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Early human settlement in the inter-Andean Magdalena valley, Colombia: New technological and chronological insights from the Nare site

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ABSTRACT

The Magdalena valley, Colombia's principal fluvial corridor, has long been recognized as a key route for early human dispersal in northern South America. This inter-Andean region served as a strategic passage between the Andean highlands and the tropical lowlands, offering a resource-rich environment that supported human mobility and settlement since the Pleistocene-Holocene transition.

In the Middle Magdalena valley, some of Colombia's oldest preceramic open-air sites have been identified. However, despite their importance, the technological characteristics of their lithic assemblages—the only direct evidence of early human activity—remain poorly understood.

This study presents the first systematic techno-economic analysis of the preceramic stratigraphic unit at the Nare site, integrating use-wear and residue analyses. Moreover, new radiocarbon dates refine the site's chronological framework, placing its main occupation in the Early Holocene.

The lithic assemblage shows a strong reliance on local raw materials (primarily quartz and chert), a predominance of unretouched flakes, some retouch flakes, and a single unifacial tool. A bladelet core suggests an interest in producing elongated, relatively standardized flakes, though the absence of bladelets raises questions about off-site transport or differential site use.

These results refine our understanding of lithic technology in the region and offer a new perspective on the Middle Magdalena's early industries, highlighting a more diverse and flexible technological repertoire. The Nare assemblage demonstrates a wide range of knapping methods, percussion techniques, and raw material management strategies.

This study enhances our understanding of early human adaptation in the region and contributes to broader discussions on lithic technologies and settlement dynamics in northern South America.

1. Introduction

The Magdalena valley, located between the Central and Eastern Colombian Cordilleras, is Colombia's principal fluvial corridor. It has long been recognized as a key route for early human dispersal in northwest South America, serving as a natural passage that linked the Andean highlands with the tropical lowlands. This connection made it a strategic axis for mobility, resource exploitation, and cultural interactions during the Pleistocene-Holocene transition (e.g., Ardila and Politis, 1989; López, 1998, 2008, 2021; Ranere and López, 2007).

The earliest human groups that explore and settle in the lowlands of northern South America were likely small, mobile populations following

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coastal plains and gradually moving inland along river valleys, taking advantage of ecological corridors with abundant resources (e.g., Aceituno et al., 2013; Delgado et al., 2015).

The Middle Magdalena Valley is an important region for investigating early human occupations, with numerous preceramic sites identified since the 1990s, mainly through the work of Carlos Eduardo López and other contract-based preventive archaeology projects, unfortunately reported only in unpublished documents (López, 1998, 1999, 2008, 2021; López and Cano, 2011).

However, research in this area has not been as extensive as desired, and significant gaps remain. In addition, geomorphological processes such as erosion and sediment deposition may have erased or buried some of the earliest evidence, making it more difficult to reconstruct past settlement patterns (López, 2008, 2021).

Archaeological research in this valley has traditionally distinguished the region as a unique technological zone within Colombia. In this context, findings in the Middle Magdalena Valley have led to the definition of the *Narense* lithic tradition, named after its eponymous site, Nare (López, 2008; López et al., 2021). Unlike the generalized, non-predetermined technologies described in other regions of Colombia—such as those at El Abra and Tibitó in the Andean highlands (Correal, 1981; Correal et al., 1969; Hurt et al., 1972; van der Hammen, 1991) or La Lindosa in the Amazon (Morcote-Ríos et al., 2021; Robinson et al., 2021)—the *Narense* has been characterized by a more structured technological framework. This definition includes both bifacial tools, such as triangular stemmed projectile points, and unifacial plano-convex scrapers, which have been interpreted as linked to specialized activities like hunting, butchery, fishing, and carcass processing (López, 2008, 2021; López et al., 2021; Ranere and López, 2007). In several sites of the Middle Magdalena Valley — Nare, Peñones, San Juan de Bedout, Palestina, and others — not only finished tools but also different stages of the operational sequence (chaîne opératoire) have been identified. This evidence strengthens the definition of the *Narense* as a distinct lithic tradition, characterized by a well-represented technological process from production to discard (López, 2008).

Despite these insights, detailed analyses of Middle Magdalena lithic assemblages remain limited, and the defining characteristics of this technological tradition require further investigation. The Nare site, with its well-preserved stratigraphic sequence spanning the Pleistocene-Holocene transition, offers a valuable opportunity to reassess these industries.

This study presents the first comprehensive techno-economic analysis of the site's earliest lithic assemblage, integrating use-wear and residue analyses. Additionally, new radiocarbon dates refine the site's chronological framework, providing a more precise understanding of its occupational sequence. By combining multiple lines of evidence, this research aims to clarify the technological organization of early human groups in the Middle Magdalena Valley. Furthermore, it contributes to broader discussions on early human dispersal in northern South America, emphasizing the region's role as both a migration corridor and a center of technological innovation.

2. Climate, landscape, and early human occupation in the Middle Magdalena Valley

The archaeological site of Nare is located within the Middle Magdalena region, a vast inter-Andean lowland in central Colombia between the Central and Eastern Cordilleras. The area shows a diverse landscape, including piedmont formations, alluvial plains, and floodplains. Vegetation varies depending on elevation, with tropical rainforest covering the valley floor and very humid premontane forests at higher altitudes. The climate is humid tropical, with an average annual temperature exceeding 24 °C and a bi-seasonal rainfall pattern ranging between 2000 and 8000 mm, depending on local conditions. The region is also rich in water resources, intersected by major rivers such as the Magdalena, Nare, Cimitarra, and Cocorná Sur (López, 2021).

Throughout the Late Pleistocene and Middle Holocene, specialized hunter-gatherers occupied diverse landscapes in the Middle Magdalena Valley, including floodplains, alluvial fan surfaces, and relict high terraces. However, despite extensive archaeological surveys, knowledge of preceramic remains—particularly their relationship with soils, stratigraphy, landscape settings, and paleoecological proxies—is still limited (López, 2021).

The earliest documented site in the Magdalena Valley for this period is Pubenza (280 m asl), located at the southern boundary of the Middle Magdalena and dated to 16,400 ± 420 ^{14}C yr BP (Correal, 1993; Correal et al., 2005). If the site suggests a contemporaneity of mastodons and humans, its reliability is uncertain due to the unclear association of dates with stratigraphic sequence, and the doubtful association between the scarce lithics and megafauna remains (Muttillo et al., 2017; Politis et al., 2009).

Following a cold and dry phase, Northern South America experienced warming between 14,600 and 12,900 cal yr BP, a period known in Colombia as the Guantiva Interstadial, corresponding to the Bølling-Allerød Interstadial (van der Hammen and Hooghiemstra, 1995). This period saw increased temperatures and precipitation, leading to the upward migration of the forest line and significant fluvio-glacial sediment accumulation in the Magdalena Valley, forming many of the paleo-terraces observed today (Berrío et al., 2001; Herrera et al., 2001; Vélez et al., 2006).

Rising lake levels in the Eastern Cordillera and intensified runoff contributed to the deposition of high-energy sediments (Vélez et al., 2006), creating new paleo-reliefs and terraces approximately 40 m in height (Martínez, 1981). Increased rainfall associated with global warming further promoted alluvial fan deposition at river confluences, while the dissection of paleo-terraces led to the erosion of many interior valley glacial sediments, likely destroying associated archaeological remains (Ardila and Politis, 1989; Aceituno et al., 2013).

Environmental changes during this period likely caused the erosion or deep burial of potential Pleniglacial cultural deposits (López, 2008; López and Cano, 2011; López and Realpe, 2015).

To date, no archaeological evidence from this period has been identified in the Magdalena Valley. It is still uncertain whether erosion removed the older layers by or if the terraces were formed only during the last deglaciation and later geomorphological transformations (López, 2008, 2019; López and Realpe, 2008, 2015).

The El Abra Stadial (12,900–11,700 cal BP), coinciding with the Younger Dryas (van der Hammen and Hooghiemstra, 1995), marked a period of climatic instability characterized by lower temperatures, reduced precipitation, and minimal sedimentation. These conditions led to the formation of reddish tropical soils in the Magdalena lowlands, indicative of a drier environment (Berrío et al., 2001; Herrera et al., 2001; Vélez et al., 2006).

During this phase, human groups occupied both floodplains and hilltops, likely adapting to shifting environmental conditions by exploiting diverse ecological niches. Archaeological evidence from sites such as Nare, Palestina, and San Juan de Bedout suggest continued human presence in the region (López, 2021).

After 11,700 cal BP, the transition to the Holocene brought increased sedimentation in the lower Magdalena Valley, with minor fluctuations in river dynamics. Between ca. 8400 and 4000 cal BP, paleoenvironmental data indicate a landscape dominated by open vegetation interspersed with patches of gallery forest, with fluctuating temperature and precipitation patterns (Berrío et al., 2001; Herrera et al., 2001). The thick alluvial deposits from the Early and Middle Holocene, less prone to later reworking, contributed to the preservation of the early depositional record (López, 1998, 1999, 2008).

3. The Nare site: chronostratigraphy and archaeological context

The stratigraphic sequence at Nare reflects this broader environmental history while also presenting site-specific depositional dynamics.

The site, commonly referred to as the Nare site (originally designated as T46 and later as 05PNA005; López, 2008), is located in the Middle Magdalena Valley region, within the municipality of Nare, in the department of Antioquia. It is on a hilltop that represents the remnant of an ancient alluvial slope, approximately 700 m south of the confluence of the Soná stream and the Nare River (Fig. 1a–c). This elongated hill, oriented east to west, rises to about 175 m above sea level and covers an area of approximately 1200 m^2 (López, 2008).

The local geomorphology is the result of the deep dissection of the Magdalena alluvial plain, which led to the formation of terraces and hills. These terraces, shaped by fluvial erosion and sediment deposition, indicate that the region has undergone significant geomorphological transformations since the Late Pleistocene. The bedrock consists of metamorphic rocks, including gneiss with amphibole and feldspar, with quartz veins outcropping about 30 m from the hilltop. The area is influenced by tectonic faults that have generated deep fractures, shaping watercourses descending from the Central Cordillera (López, 2008).

The site was discovered when an exposed 50-m-long profile revealed a stratigraphic sequence of reddish soil horizons containing buried cultural remains (López, 1998, 1999). Following extensive test pitting on the terrace summit, a 9 m^2 excavation was conducted in 2000 using a controlled methodology with 5 cm artificial levels to ensure precise

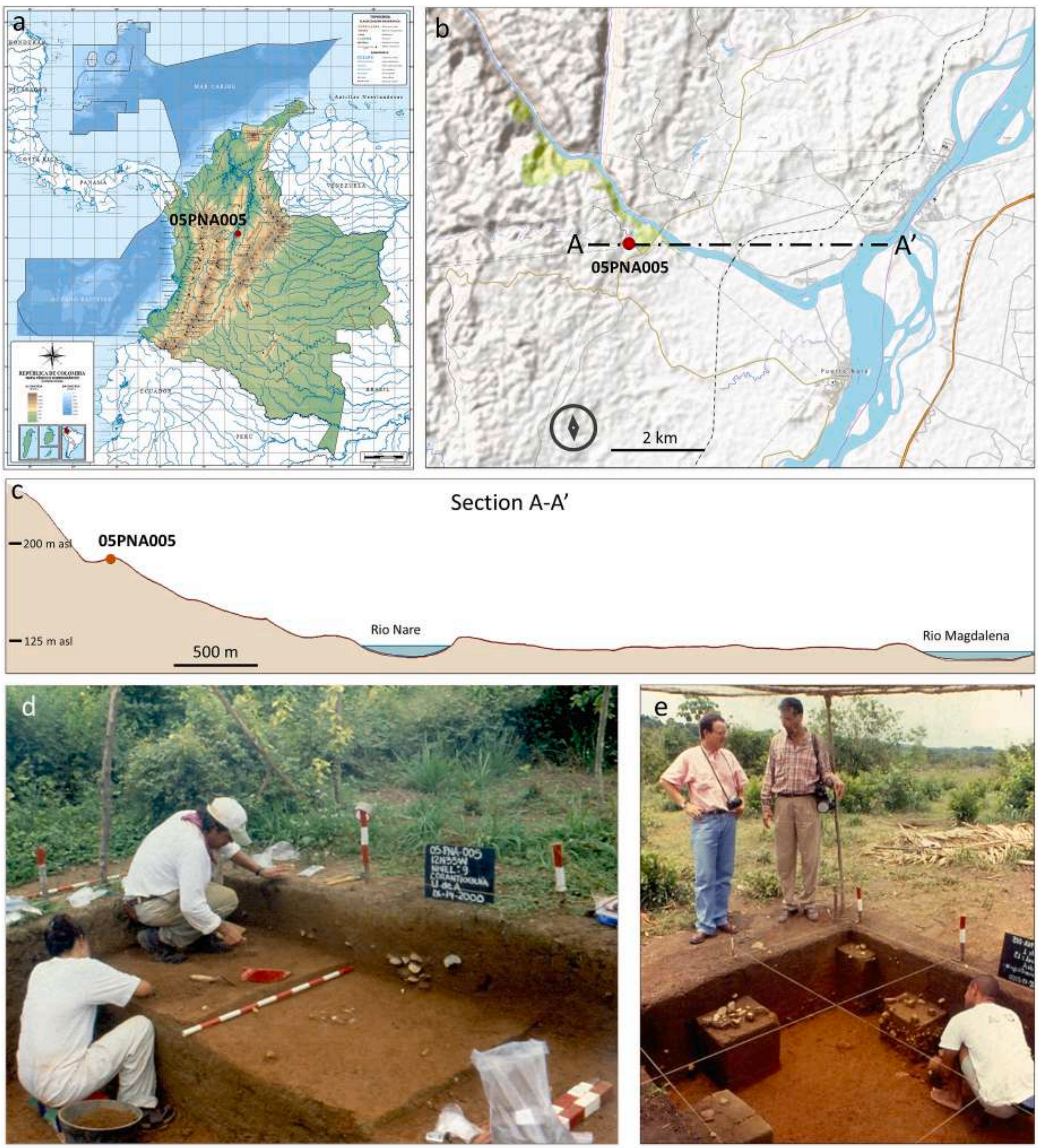

Fig. 1. Location of the Nare site (05PNA005) at the national scale within Colombia (a) and at the regional scale in the Middle Magdalena Valley, showing its position relative to the Magdalena and Nare rivers (b). Elevation profile of site 05PNA005 in relation to the Magdalena and Nare rivers (c). Excavation scenes from the 2000 fieldwork campaign (d, e). Maps by G. Lembo; photos from the Carlos López archive. (a) Base map from Wikimedia Commons, created by Milenioscuro and licensed under Creative Commons Attribution-ShareAlike 3.0 Unported (CC BY-SA 3.0): https://commons.wikimedia.org/wiki/File:Mapa_de_Colombia_(relieve).svg. (b) Map generated using OpenStreetMap. (c) Elevation profile generated using Google Earth.

stratigraphic recording (López, 2008).

The excavation yielded nearly 5000 lithic artifacts but no faunal remains. The assemblage includes flakes, cores, thinning flakes (particularly bifacial), and retouched tools. Based on these findings, the authors interpreted the site as a multicomponent occupation with evidence of a specialized lithic workshop during the early Holocene. Ceramics, found exclusively in the uppermost horizon, suggest a later phase of use

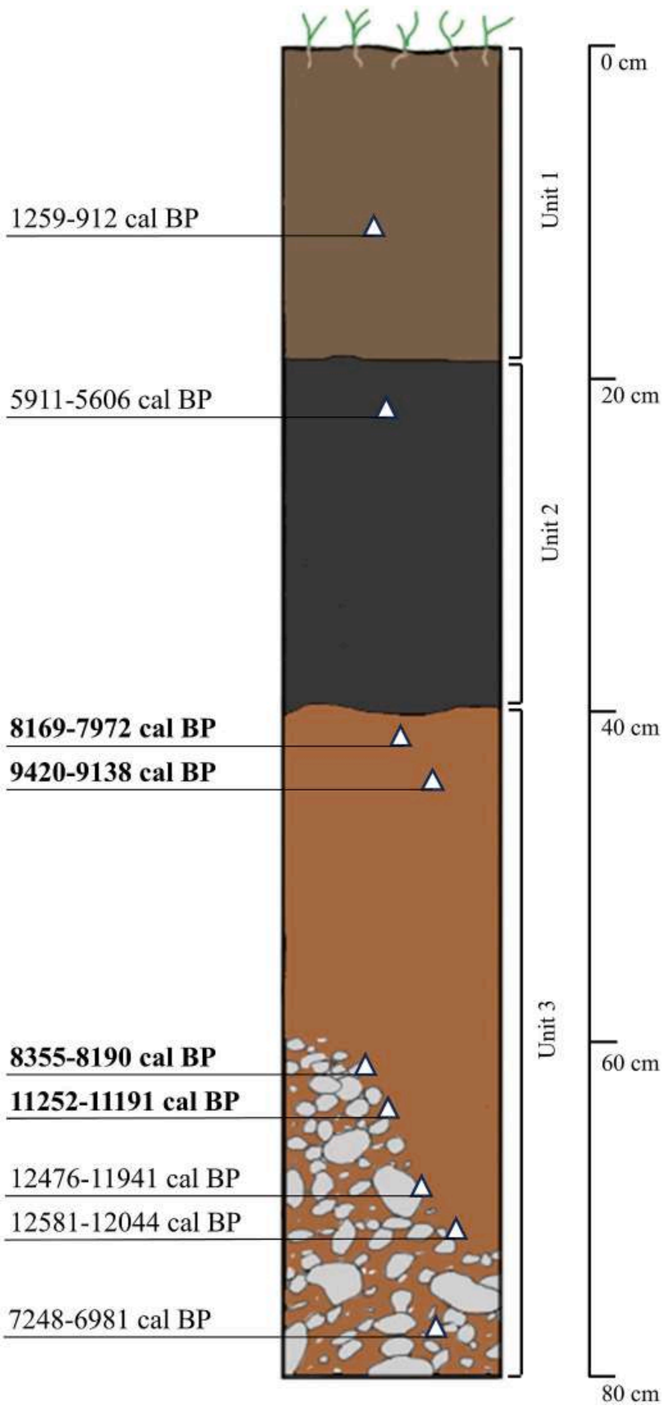

Fig. 2. Schematic stratigraphic profile of the Nare site. Stratigraphic units are shown with associated radiocarbon dates (indicated by white triangles). New dates obtained in this study are shown in bold. For additional details, see Table 3. All radiocarbon ages were calibrated using OxCal 4.4 with the IntCal20 calibration curve. The date of 7248–6981 cal yr BP (obtained at 75 cm depth) was discarded by López (2008).

(López, 2008).

The stratigraphic sequence of the site reveals multiple occupational episodes (López, 2008) (Fig. 2).

Stratigraphic Unit 1 (ca. 0–20 cm depth) consists of a dark brown clayey-sandy matrix containing ceramics, lithic artifacts, and charcoal. It shows clear evidence of bioturbation and erosion-related fissures, which have resulted in a mixing of archaeological and modern materials.

Stratigraphic Unit 2 (ca. 20–40 cm depth) is composed of a silt-clay-sandy matrix with a dark color that becomes noticeably more intense around 25 cm, possibly indicating a buried soil horizon. No bioturbation has been observed. The deposit includes coarse sand and occasional gravel, and the number of lithic artifacts increases compared to the overlying unit.

Stratigraphic Unit 3 (ca. 40–80 cm depth) has a loamy-clay to clayey texture and is characterized by a reddish coloration. Like Unit 2, it shows no signs of bioturbation. The deposit contains lithic artifacts, charcoal, and gravel, and is associated with a preceramic occupation.

From approximately 60 cm depth onward, the matrix becomes increasingly rich in cobbles and gravels, with scattered lithic artifacts and charcoal granules. This portion of the unit is interpreted as associated with paleochannel activity.

Radiocarbon dating placed this level at the transition between the Pleistocene and Holocene, representing the earliest occupational phase at the site. However, a date of 7248–6981 cal yr BP obtained at 75 cm depth was discarded by the authors, as it likely reflects the intrusion of younger charcoal due to bioturbation (possibly caused by roots or soil-dwelling organisms) (López, 2008) (Fig. 2; Table 3).

The sedimentary record at Nare terrace indicates a fluvial depositional context, with sediment inputs from both the Eastern and Central Cordilleras. Younger sediment deposition appears to have been closely associated with the presence of a stream or a branch of the braided paleo-Nare River, which influenced the accumulation of materials at the site (López, 2008).

The presence of gravels and small pebbles at various depths in the lower excavation levels suggests that a slow-moving paleocurrent was responsible for depositing these materials. Archaeological artifacts, clearly modified by human activity, were found both above and within these gravel layers across multiple sectors, indicating that human occupation occurred in connection with fluvial deposition processes. This suggests that the site's formation was closely tied to the development of the terrace, implying that the area was once characterized by wetlands and subject to frequent flooding across an extensive floodplain.

Despite these dynamic fluvial conditions, the Nare site appears to have remained relatively stable and was not significantly impacted by erosion during the Early and Middle Holocene. It was only around 3000 years ago, when the broader Magdalena fluvial system began to lower, that erosion processes intensified, ultimately shaping the site into the elevated landform observed today (López, 2008, 2021; López and Realpe, 2015).

Table 1
Components of the lithic assemblage.

Components	n.	%
Whole cores	2	*1*
Whole flakes	40	*14*
Broken flakes	108	*39*
Retouched flakes	1	*0.5*
Unifacial shaped tools	1	*0.5*
Debris	113	*41*
Natural fragments	6	*2*
Heat detachments	8	*3*
Total	**279**	***100***

4. Materials and methods

4.1. Lithic analysis

4.1.1. Techno-economic analysis

This study presents the first detailed technological analysis of the lithic assemblage from the oldest stratigraphic unit at the Nare site, SU 3—specifically, artificial levels 9 to 16, corresponding to a depth of 40–80 cm. A total of 279 lithic artifacts were analyzed (Table 1); these are currently housed at the *Laboratorio de Ecología Histórica y del Patrimonio Cultural* at the *Universidad Tecnológica de Pereira*, Pereira, Colombia.

The results are presented collectively for all artificial levels, as they were interpreted as part of a single stratum and no significant technological differences were observed between them. The only notable variation concerns the quantity of artifacts, which is low in the deeper levels (Fig. 3) and gradually increases toward the upper levels.

Previous studies of the lithic industry at Nare primarily focused on a general techno-typological assessment (López, 2008), use-wear and residue analysis conducted by Nieuwenhuis (2002). However, the stratigraphic provenance of the analyzed materials is unknown, preventing a direct correlation between those artifacts and the assemblage examined in the present study.

This study adopts a techno-economic approach based on the chaîne opératoire concept (Inizan et al., 1999; Leroi-Gourhan, 1964; Perlés, 1991), reconstructing the sequential processes of lithic production, from raw material procurement to tool manufacture, use, maintenance, and discard.

The analysis involved the examination of the physical state of the lithic artifacts, including their preservation and integrity, as well as their technological classification and position within the *chaîne opératoire*. The assessment of lithic reduction strategies was based on the combined study of flakes and cores. Core analysis focused on number and configuration of flaking surfaces, core volume management, direction of flaking, presence/absence of prepared striking platforms, number of flaking surfaces and their relationships, core volume management, evidence of core maintenance, reduction intensity, and abandonment criteria. Flake analysis has included key technological attributes to distinguish different reduction strategies, techniques and stage of lithic reduction: dorsal scar patterns, butt and bulb characteristics, platform attributes, flaking angles, cortex distribution.

In this study, we follow the definitions of flaking and shaping as outlined by Inizan et al. (1999). Additionally, blade debitage is defined as a pre-planned reduction strategy aimed at producing standardized elongated blanks, where the length is at least twice the width (Inizan et al., 1999).

The retouching process, aimed at modifying flake edges to create tools, was analyzed by examining its delineation, extension, angle, localization, morphology, and distribution (Inizan et al., 1999). This was also correlated with the flaking method, blank size, and tool morphology to investigate possible standardization in tool production.

Percussion techniques were evaluated following criteria established in experimental studies (Pelegrin, 1991, 2000; Soriano et al., 2007).

A key aspect of the analysis was the identification of retouch and resharpening flakes, which provide insights into tool maintenance and reuse strategies. Retouch flakes are flakes removed intentionally to modify the edge of a tool during manufacture, re-sharpening, or reworking with the intention of making, finishing or sharpening tools (Inizan et al., 1999).

Resharpening flakes are defined as flakes removed intentionally from the edge of a used tool to resharpen its edge (Chan et al., 2020). Their recognition was based on the observation of a previous retouched edge removed by the resharpening flake (Lazuén and González-Urquijo, 2015).

4.1.2. Use-wear analysis

A preliminary test was conducted on a sample of nine lithic artifacts from the Nare site with two main objectives: (1) to assess the overall preservation of the assemblage and (2) to verify the presence and distribution of use-wear. This evaluation aimed to determine whether the assemblage was suitable for more detailed functional analyses in the future.

The sample primarily consisted of unretouched flakes ($n = 7$), along with a resharpening flake and an unifacially shaped tool. Four flakes and the tool were made of chert, three flakes of quartzite, and one flake of quartz.

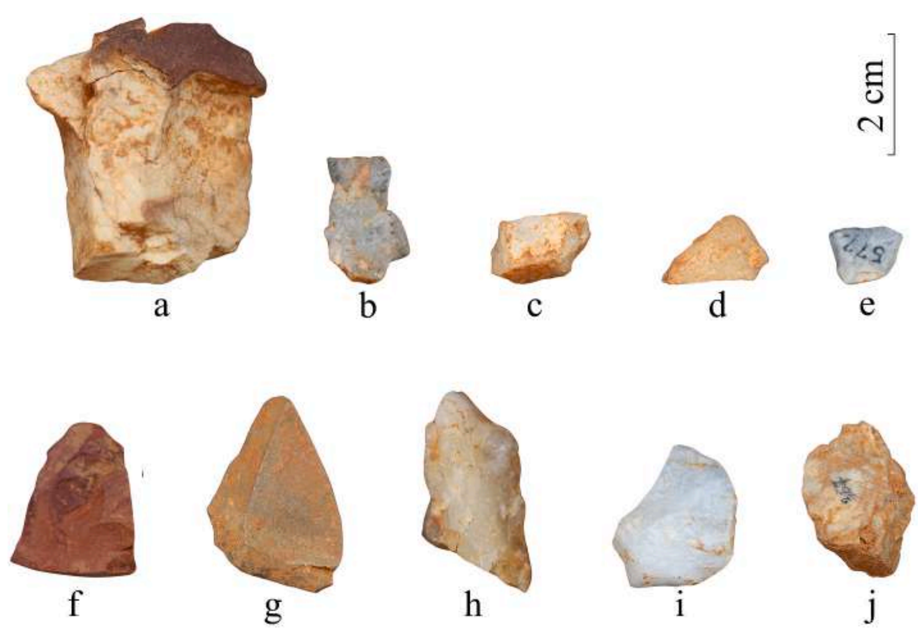

Fig. 3. Flake fragments from the lowest artificial cuts, made of quartz (c-f, h-j) and chert (a-b, g). Photo: G. Lembo.

The artifacts were examined at low magnification (5–200x) using a DinoLite 5 MP Edge Digital Microscope with reflected light to identify potential post-depositional modifications caused by mechanical and tribo-chemical agents (Burroni et al., 2002; Caux et al., 2018; Galland et al., 2019). Additionally, the analysis aimed to detect macro use-wear, such as edge damage (scarring and rounding), which provides insights into the hardness of the worked material (e.g., soft, medium, hard) and the motion performed by the implement (e.g., longitudinal, transversal, or combined gestures) (Odell, 1981; Odell and Odell-Vereecken, 1980; Tringham et al., 1974).

4.1.3. *Residue analysis*

Although the artifacts originate from old excavations and are now part of laboratory collections, some *in situ* residues were observed and analyzed, whereas contaminants (e.g., handling, synthetic fibers) were identified microscopically and excluded from further examination.

Five implements with potential residues were identified, including an unifacially shaped chert tool and four flakes in chert and quartzite. However, two samples were too small for retrieval, and another was discarded due to contamination from synthetic material. The residue on the unifacially shaped tool was identified as sediment with organic signals but was excluded due to the assemblage's uncertain condition.

Only one sample (ID 378), a flake in quartzite, met all criteria for further analysis: i) *in situ* residue, ii) no visible or detectable contamination, iii) close relation to an intensively worked edge. This made it suitable for multi-technique testing.

Sample 378B was collected under microscopic observation using a DinoLite 5 MP Edge Digital Microscope with reflected light (10 × - 220 × magnification) and documented before and after collection. All samples were stored in labeled Eppendorf vials and shipped to the *Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università degli Studi di Siena*, Italy. As part of a larger Synchrotron Radiation (SR) Fourier Transform InfraRed (FTIR) spectroscopic study (Dominici, 2024), they were analyzed at the SISSI-Bio, Chemical and Life Science beamline of *Elettra Sincrotrone Trieste* (Basovizza, Italy) (Birarda et al., 2022).

4.1.3.1. SR-FTIR microscopy. For SR-FTIR microscopy, sample 378B was transferred onto a diamond compression cell (Diamond EX-press by S.T. Japan, clear aperture 2.0 mm) to be flatten to a thickness suitable for measurements in transmission mode (Dominici et al., 2022; Sano et al., 2019). A Stand K LAB ZEISS Stemi 305 equipped with reflected light LED electronics and tiltable mirror-based transmitted light unit with manual zoom magnifications ranging from 0.8 × to 4.0 × was used during this operation. The diamond compression cell was opened again after the compression. The sample was then analyzed with a Bruker VIS-IR Hyperion 3000 microscope equipped with an MCT-A detector operating in the Mid-IR range (4000 - 650 cm^{-1}) and coupled with a Bruker VERTEX 70v interferometer. SR-FTIR measurements were collected in transmission mode setting the lateral resolution at 15 × 15 µm at 4 cm^{-1} spectral resolution, averaging 512 scans with scan velocity of 120 kHz. OPUS 8.5 software (Bruker) was used for spectra acquisition, preprocessing, averaging, and analysis.

4.1.3.2. Optical – Photothermal InfraRed (O-PTIR) spectroscopy. After SR-FTIR microscopy, colocalized infrared and Raman spectra were acquired on the same sample with an O-PTIR MIRage-LS System (Photothermal Spectroscopy Corporation, Santa Barbara, California, USA). The instrument is equipped with a series of pulsed (100 kHz of pulse rate and 100 ns pulse width) tunable quantum cascade lasers (QCL) (MIRcat-QT, Daylight Solutions Inc.) covering the wavenumber ranges of 3000 - 2700 cm^{-1} and 1850 - 790 cm^{-1}, used as "pump" beam, while a co-focused continuous-wave single-frequency 532 nm laser was used as the visible "probe" beam. The power of the lasers was set at 80 % and 0.26 % for the pump and probe beams, respectively. All the measurements were performed in co-propagation mode, using a 40x Cassegrain objective, and an Avalanche PhotoDiode (APD) detector. IR spectra were collected averaging 12 scans a spectral resolution of 2 cm^{-1}. For Raman, 15 averages were collected in the range 4091 - 257 cm^{-1} with a point density of 3,84 cm^{-1}/pt (resolution 600, integration 2 s). The software PTIR Studio 4.6 from the same company was used for both data acquisition and visualization.

4.1.3.3. Reference libraries. SR-FTIR and Raman spectra were compared with the IRUG spectral database (www.irug.org), the Kimmel Center for Archaeological Science Infrared Standards Library of the Weizmann Institute of Science (https://centers.weizmann.ac.il/kimmel-arch/infrared-spectra-library) and the RRUFF database from the California Institute of Technology (https://rruff.info/).

4.2. *^{14}C analysis*

Four charcoal samples were selected from the stratigraphic unit 3. Two were taken from artificial cut level 9 at a depth of 40–45 cm, whereas the remaining two were collected from artificial cut level 13 at a depth of 60–65 cm.

The samples were pretreated following the protocol outlined by Tassoni et al. (2023). The biggest samples were crushed into fine powder or smaller grains, weighing approximately 70–150 mg.

At the BRAVHO lab (Bologna, Italy), each sample underwent treatment with 2M HCl at 60 °C for 1 h in a heating block to eliminate carbonate contamination. Any humic acid contamination was then addressed using a 1M NaOH solution at 60 °C for 30 min. This step was repeated until the solution remained clear, with ultrapure water rinses between each stage. The chemical process concluded with a second application of 2M HCl to remove any atmospheric CO_2 absorbed by the sample. Finally, the samples were dried in an oven at 70 °C for 1–2 days.

The processed carbon was then graphitized at the BRAVHO lab (Tassoni et al., 2023) using the Elementar vario ISOTOPE select in combination with the AGE 3 Automated Graphitization Equipment (IonPlus AG, Switzerland) (Wacker et al., 2010a). The resulting graphite targets were sent to the Curt-Engelhorn-Center for Archaeometry in Mannheim, Germany (CEZA, lab code: MAMS) and measured using a MICADAS AMS (Kromer et al., 2013).

5. Results

5.1. *Lithic analysis*

The assemblage is primarily composed of flakes ($n = 148$, of which only 40 are complete) and debris. Additionally, two whole cores, a retouched flake, and an unifacially shaped tool were identified. Natural fragments and heat-related detachments are rare. A total of eight chert artifacts exhibiting thermal fractures were documented within the assemblage (Table 1). These artifacts show characteristic alterations associated with exposure to high-temperature fires, as described in the literature. These include color changes (e.g., the development of a reddish hue) and the presence of potlidding—a typical effect of thermal stress (e.g., Abdolahzadeh et al., 2023; Domanski and Webb, 1992) (Fig. 3-f).

Raw materials were classified macroscopically based on composition, texture, and color. For analytical consistency, they were grouped into three broad categories: chert, quartzite, and quartz (Fig. 4).

The Nare lithic assemblage is predominantly composed of quartz (50 %) and fine-grained chert (41 %), with a minor presence of quartzite (9 %) (Fig. 5).

No evidence of exotic raw materials was found, indicating that lithic production relied exclusively on locally available resources. The widespread availability of high-quality cryptocrystalline materials in the Magdalena floodplain and adjacent piedmont significantly minimized the effort required for raw material procurement. These resources could

Fig. 4. Microphotographs (80x magnification) of the different raw material types used.

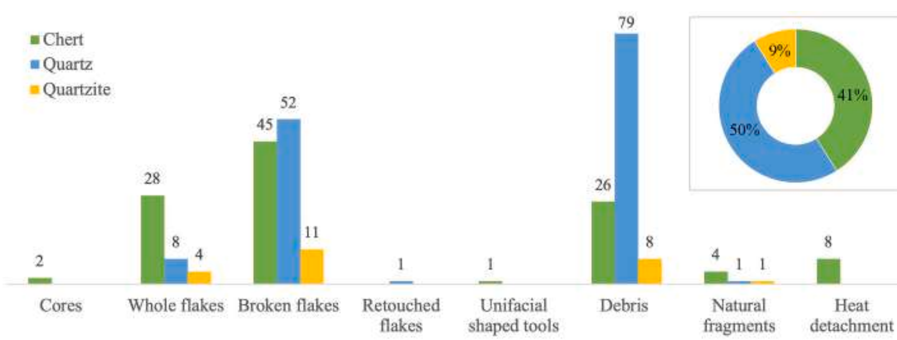

Fig. 5. Proportion of exploited raw materials (chert, quartz, and quartzite) represented as a percentage (in the box). Distribution of raw materials across different technological categories, shown in a bar chart.

be easily collected from accessible locations such as modern and paleo-beaches, the main Magdalena channel, old channels, tributaries, and riverbeds (López, 2008, 2021; López and Realpe, 2015).

Although the limited sample size prevents definitive conclusions about raw material preferences, the data suggest a tendency to use chert for core preparation, flake production, and tool manufacture. This preference is likely due to chert's homogeneity, fine grain, and predictable fracture patterns. Quartz, on the other hand, shows a higher proportion of broken flakes and debris (Fig. 5), reflecting its less favorable knapping properties, as documented in the literature (e.g., de Lombera-Hermida and Rodríguez-Rellán, 2016; Driscoll, 2011; Rodríguez-Rellán, 2016; Tallavaara et al., 2010).

5.1.1. *Lithic assemblage in chert*

Chert, varying in color from yellow to reddish and gray to black (Fig. 4), is fine-grained and free of inclusions, making it highly suitable for knapping. It originates from the Eastern Cordillera and occurs as nodules and cobbles in Pleistocene and Holocene terraces of the Magdalena Valley, as well as in riverine contexts (López, 1999, 2008, 2021).

The *chaîne opératoire* for chert exploitation is evidenced by two cores, 73 flakes (mostly fragmented), and an unifacially shaped tool (Fig. 5).

Cores. Two cores were identified, both derived from thick flakes but exploited using different methods: one as an unifacial multidirectional core, the other as a bladelet core.

The unifacial multidirectional core was made from a thick first flake of a chert cobble, which served as the initial blank. The ventral face was used as the debitage surface, producing five small sub-quadrangular flakes in a multidirectional pattern (Fig. 6). These flakes display cortical or plain butts, with two showing hinged terminations.

The bladelet core follows a volumetric conception (Fig. 7). Debitage

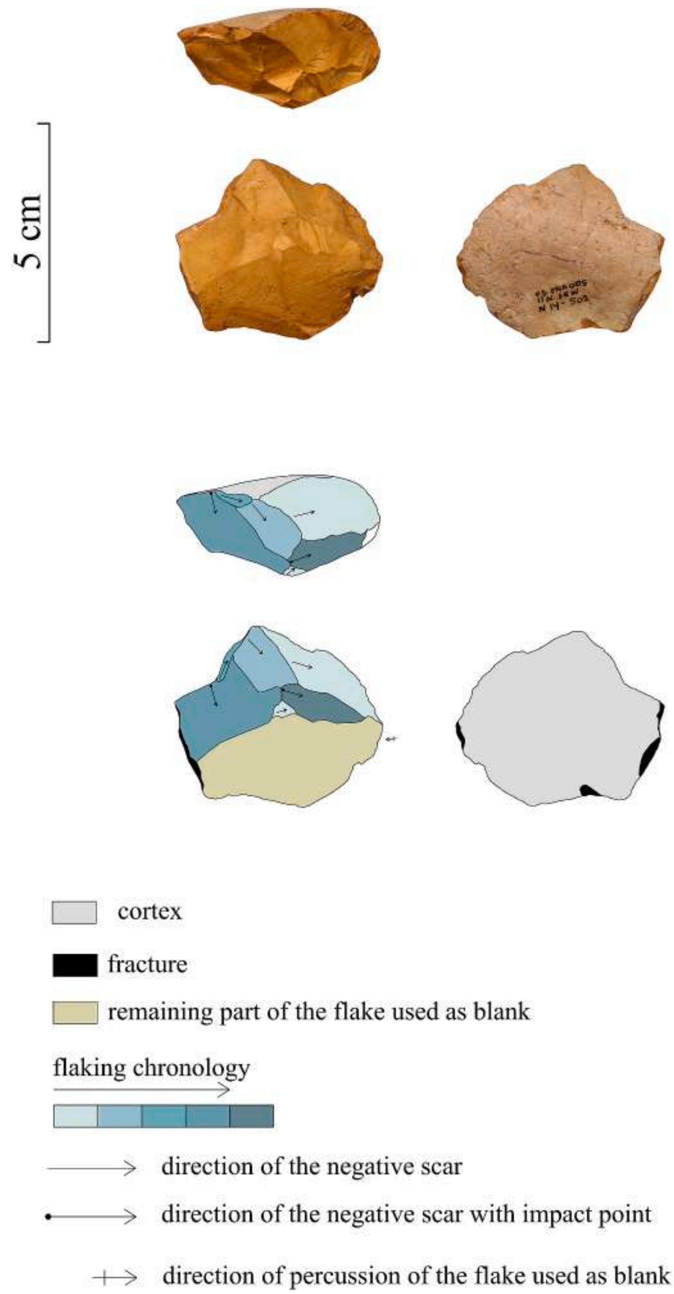

Fig. 6. Unifacial multidirectional core in chert (Photo and drawings: G. Lembo).

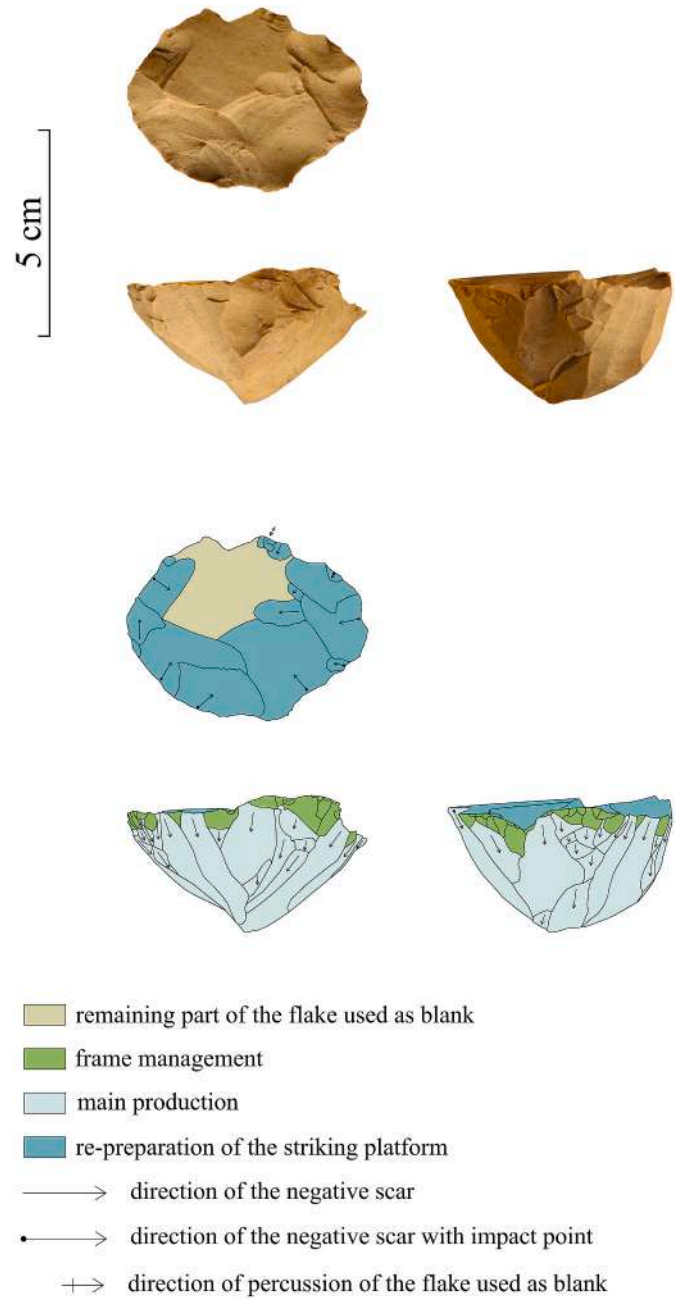

Fig. 7. Bladelet core in chert (Photo and drawings: G. Lembo).

began from a striking platform corresponding with the ventral face of the thick flake, utilizing its natural plain platform without prior preparation. Convergent removals from this single platform shaped the core into a half-pyramidal form with irregular angles. The resulting scars indicate the production of convergent and sub-convergent bladelets. Although the products are not entirely standardized, the intent to produce elongated bladelets is evident.

Core maintenance was performed through centripetal removals along the lateral and distal edges, ensuring the preservation of convexities throughout the reduction sequence. The striking platform was re-prepared using centripetal detachments before the core was ultimately discarded. Hinged detachments may have played a role in this process.

Notably, the initial flake blank was not particularly large, suggesting that the core was deliberately designed for bladelet production. Using a thick flake as a starting support minimized initialization phase, enabling direct debitage without additional preparation.

Although no bladelet products matching this core were found in the assemblage, the negatives of the removals suggest direct percussion with a soft hammer, possibly organic or soft stone. These techniques, known to produce similar stigmata, facilitate the controlled production of elongated bladelets (Pelegrin, 2000; Pelegrin and Inizan, 2013).

Flakes. Most flakes are wider than they are long, with an average size of 22.2 × 24.9 × 7.5 mm. Only one flake has a length-to-width ratio greater than 2 (2.7), but it lacks laminar characteristics.

Flake dimensions are consistent with those of the quartz assemblage but exhibit a broader size range (Table 2).

Most flakes display unidirectional negative scars on the dorsal face, aligned with the flaking direction and occasionally slightly convergent. Orthogonal and multidirectional scars are less frequent. Cortical areas are present on 15 flakes, including one fully cortical flake and two *éclats d'entame* (first flakes) linked to cobble exploitation. Bipolar-on-anvil

Table 2
Table showing dimensions (in mm) of the whole flakes grouped by raw material. S.D. (= Standard deviation).

Whole flakes	n.	%	Length				Width				Thickness			
			Mean	Max	Min	S.D.	**Mean**	Max	Min	S.D.	**Mean**	Max	Min	S.D.
Chert	28	*70.0*	**22.2**	42	7	9.8	**24.9**	52	9	12.9	**7.5**	22	2	5.6
Quartz	8	*20.0*	**27.2**	68	8	17.6	**25.3**	61	9	16.3	**8.1**	14	3	4.1
Quartzite	4	*10.0*	**43**	79	23	26	**45.7**	84	21	29.2	**16**	30	6	11.2
Total	40	*100.0*												

Table 3
Radiocarbon dating of the analyzed charcoal samples. Four new dates, labeled with the prefix BRA-, were obtained at the BRAVHO laboratory in Bologna. The samples were processed according to the protocol described by Tassoni et al. (2023) and measured using AMS at the Curt-Engelhorn-Center for Archaeometry in Mannheim, Germany (CEZA, lab code: MAMS). The remaining five dates are from López (2008), but no information is available regarding their preparation and measurement protocols. All radiocarbon ages were calibrated using OxCal 4.4 with the IntCal20 calibration curve.

Sample Code	Stratigraphic unit	Depth (cm)	Material	AMS Code	^{14}C BP	1σ Err	Cal BP age (68.3 %)	Cal BP age (95.4 %)	References
Beta-144079	1	10–15	charcoal	–	1120	70	1175–936	1259–912	López (2008)
Beta-144080	2	20–25	charcoal	–	5040	60	5895–5726	5911–5606	López (2008)
BRA-7088	3	40–45	charcoal	MAMS-65673	7238	27	8163–7979	8169–7972	This work
BRA-7094	3	40–45	charcoal	MAMS-65674	8286	26	9406–9147	9420–9138	This work
BRA-7098	3	60–65	charcoal	MAMS-65676	7462	26	8341–8209	8355–8190	This work
BRA-7092	3	60–65	charcoal	MAMS-65675	9803	28	11238–11206	11252–11191	This work
Beta-70040	3	65–70	charcoal	CAMS-11742	10350	60	12453–12003	12476–11941	López (2008)
Beta-146798	3	65–70	charcoal	Beta – 146798	10400	40	12473–12104	12581–12044	López (2008)
Beta-146799	3	75–80	charcoal	Beta – 146799	6200	40	7162–7014	7248–6981	López (2008)

percussion is evidenced by three flakes exhibiting characteristic features of split pebbles, including opposite impact points on the ventral face (Fig. 8f and g). Three flakes have cortical lateral backs, two have a backed lateral edge. Butts are predominantly natural and plain, with some linear, punctiform, and dihedral forms. Bulbs are diffuse and weakly pronounced.

Eight small retouch/finishing flakes were identified. These flakes, characterized by plain and linear butts and unidirectional or orthogonal scars on the dorsal face, are thinner (3–6 mm) than the average assemblage. The presence of a pronounced lip, diffuse bulbs, and an average flaking angle of 70° suggests soft (possibly organic) percussion (Pelegrin, 2000; Pelegrin and Inizan, 2013).

Among them, two flakes may correspond to resharpening flakes, as they appear to have been intentionally removed to refresh a previously retouched edge. Further analysis is needed to confirm potential use-wear traces on these specimens (Fig. 8j and k).

Tools. The assemblage includes an unifacially shaped tool in chert (Fig. 9), previously referred to as an unifacial plano-convex tool (López, 2008, 2021). In line with recent studies in Colombia (González-Varas et al., 2023), we adopt the term unifacially shaped tool to emphasize both the shaping process and the unifacial nature of the artifact.

This small artifact (69 × 50 × 24 mm) has an ovoid shape with a plano-convex section. It features two asymmetric faces: a flat ventral face (the unmodified surface of a flake) and a shaped dorsal face. Its lateral edges are slightly convex and convergent, while its overall morphology exhibits asymmetry along both longitudinal and lateral axes. The base is broader and thicker; the distal part is narrower and sharper.

The tool was shaped by working the periphery of the dorsal face, leaving the ventral face largely untouched except for a few initial removals, likely to adjust minor convexities or reduce an overly prominent bulb. The original striking platform is absent, though a faint bulb and propagation waves from the impact point remain visible. Additionally, the tool's axis does not align with the initial flaking axis.

The production followed three main phases:

1. Flaking: detachment of a thick flake, likely using a hard hammer.
2. Shaping: large, invasive removals were applied to the dorsal face, extending from the edge toward the center and converging along a longitudinal ridge. Edge angles range from 45° to 65°, suggesting the use of direct percussion with a soft hammer.
3. Finishing: refinement of the edges through short, scaled, and localized retouching to achieve the intended morphology.

Due to its homogeneous state of preservation, no clear evidence of re-sharpening is identifiable. The observed modifications likely belong to the original finishing process, though a re-sharpening episode shortly after initial use cannot be entirely ruled out.

Lithic assemblage in quartz.

Quartz, present in various forms — including milky, rose, crystalline, and semi-crystalline (Fig. 4) — was sourced from local secondary deposits, most likely originating from the Central Cordillera (López, 2008).

The quartz assemblage consists of 79 debris pieces and 60 flakes, only eight of which are complete (Fig. 5, b). A single fragment—a mesial portion of a flake—displays short, denticulate, direct retouch along one edge. No cores were identified. The dimensions of the complete flakes indicate a small size range, averaging 27.2 × 25.3 × 8.1 mm (Table 2).

Dorsal scar patterns on whole flakes range from two to five removals, predominantly unidirectional. Two flakes have lateral dorsal scars that removed parts of the core platform, one is a plunging flake.

The butts are evenly split between plain and natural types, with bulbs that are diffuse and minimally pronounced. Cortical traces appear on eight flakes, and in six cases, the starting blank could be identified as a pebble.

Lithic assemblage in quartzite.

The worked quartzite assemblage is very limited, consisting of only a few flakes and some debris (Fig. 5). Flakes are slightly larger on average than those in chert and quartz (Table 2), though this difference is likely skewed by the small sample size.

Most flakes retain cortical remnants on their dorsal faces, indicating pebble and cobble exploitation (Fig. 8e and f). One is an *éclat d'entame* (initial flake from cobble opening), two exhibit bipolar-on-anvil percussion features. Additionally, five flakes display cortical lateral backs.

Butts are mostly natural, with one plain butt. Dorsal removals are few (one to three), with unidirectional and orthogonal patterns equally represented, and a single multidirectional example. This assemblage reflects early-stage debitage.

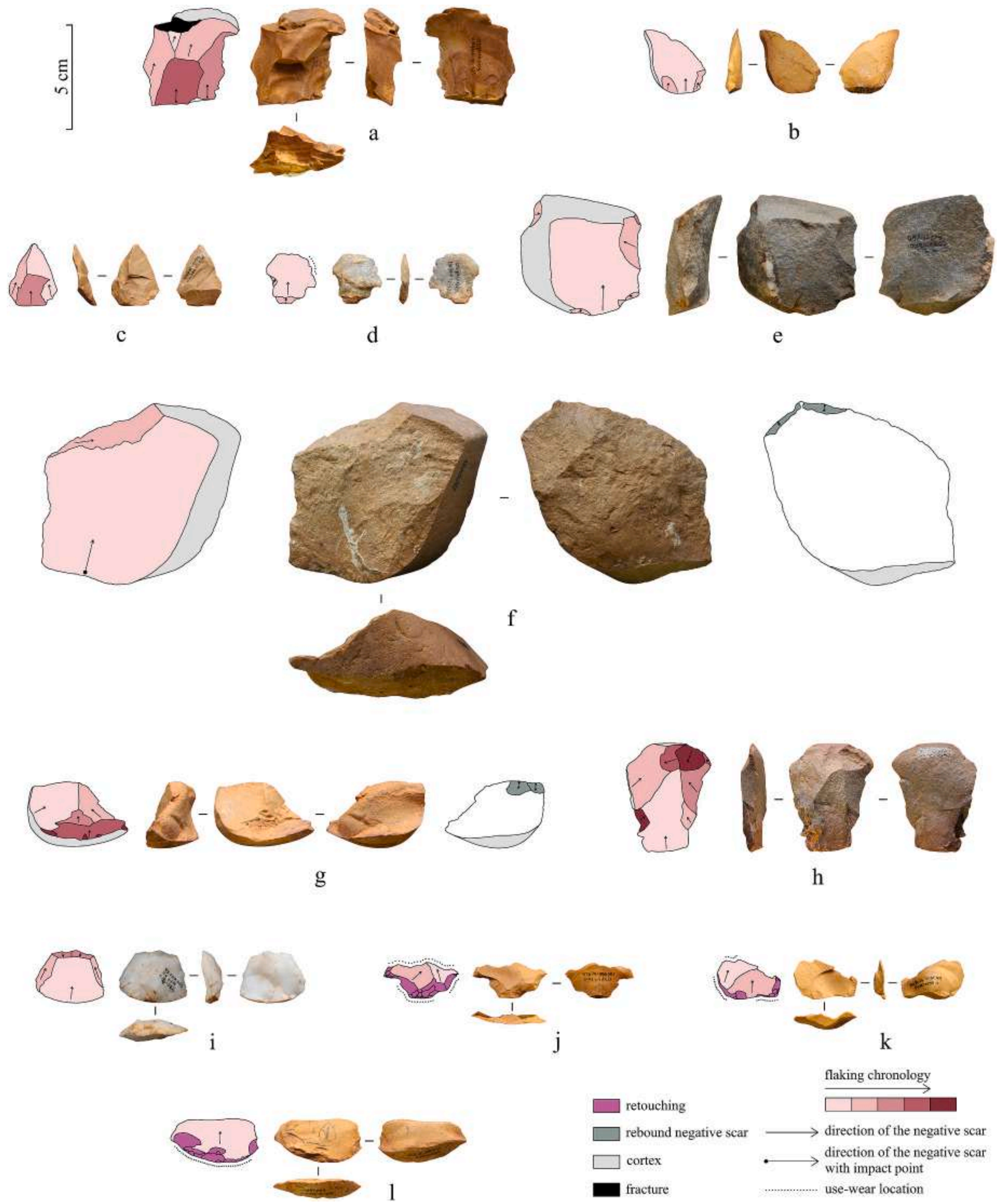

Fig. 8. Flakes with a unidirectional negative scar pattern on the dorsal face (a–d). Flakes with an orthogonal negative scar pattern (e–f). Flakes with a multidirectional negative scar pattern (g–i); (f) and (g) were likely produced by bipolar-on-anvil percussion. Retouch/resharpening flakes (j–l) (Photo and drawings: G. Lembo).

5.1.2. *Use-wear analysis*

The analyzed artifacts are generally well preserved, with an occasional occurrence of post-depositional traces mainly consisting in edge scarring identified on two flakes. Four items show traces of unclear origin.

Use-related traces were identified on the unifacially shaped tool, which displays intense edge rounding accompanied by small, transversely oriented scars along the tool's main axis, with feather terminations (Fig. 10a and b). These features suggest it was used to process medium to soft materials, possibly using some abrasive substances.

Two chert flakes also display possible use-related traces, located on the distal part of the edge. These include edge rounding and small to medium-sized scars showing feather and step terminations with an oblique orientation (Fig. 10, c). This suggests they were likely used for cutting medium to soft materials.

5.1.3. *Residue analysis*

The residue location on artifact 378 and its appearance during

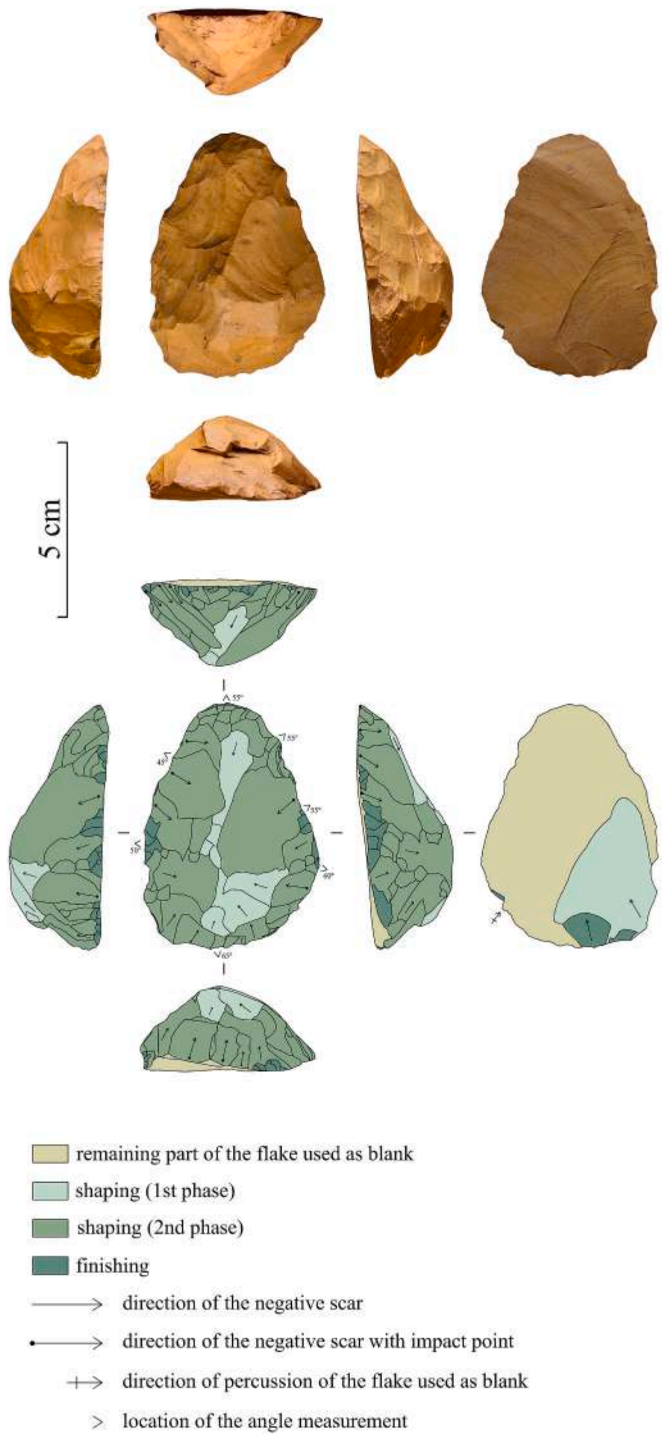

Fig. 9. Unifacially shaped tool in chert (Photo and drawings: G. Lembo).

preliminary observation are shown in Fig. 11a and b, while the same area after sample collection, showing direct contact with the lithic surface, is presented in Fig. 11c. Fig. 11d and e shows the sample onto the bottom window of the diamond compression cell, before (d) and after (e) the compression. The sample shows a homogeneous, intense, dark red color in both the pictures, as seen under the ZEISS Stemi 305 stereomicroscope.

The SR-FTIR spectra collected from the sample gave homogeneous spectral features in all the twenty (15 × 15 μm) spots measured (Fig. 11f). The average spectrum reported in Fig. 11g, shows peaks at 3694, 3621, 1035, 1014 and 913 cm^{-1} which can be attributed to clay minerals of the kaolin group, and in particular of kaolinite ($Al_2Si_2O_5(OH)_4$) (Madejová et al., 2017). A reference spectrum of this mineral (from the Kimmel Center for Archaeological Science Infrared Standards Library) is shown alongside the Average spectrum of the sample 378B for comparison (Fig. 11g). The broad band at around 1600 cm^{-1} can be attributed to C=C stretching in aromatic compounds possibly suggesting the presence of organic acids (Machado et al., 2020), while the peaks at around 1410 cm^{-1} can be indicative of the presence of carbonates.

Comparable features at 1550, 1417 and ~1040 cm^{-1} (Fig. 11h) were observed in the infrared O-PTIR spectra. Colocalized Raman spectra have been collected on the same sample to further investigate the possible presence of iron oxides potentially responsible for its intense color and retrieve more information on its composition. Raman spectra show two main peaks at 400 and ~290 cm^{-1}, accompanied by a peak at ~656 cm^{-1} with a shoulder at 610 cm^{-1}. An additional spectral feature at around 500 cm^{-1} was also observed, together with a very intense peak at 1316 cm^{-1} (Fig. 11j). These features are indicative of the presence of a mixture of hematite (Fe_2O_3) and clay minerals such as kaolinite, commonly referred to as red ochre (see Dominici et al., 2023 for a discussion). The intensity enhancement of the peak at 1316 cm^{-1} is due to a resonance effect, since the 532 nm wavelength of the laser used for probing is very close to the 580 nm absorption edge of Fe_2O_3 (Marucci et al., 2018).

5.2. *New radiocarbon dating*

For quality assurance, a portion of a background wood sample (with a radiocarbon age exceeding 50,000 years) was processed alongside the samples to monitor and correct for any potential contamination during lab procedures. Data reduction was performed with BATS software (Wacker et al., 2010b), with an additional 1 ‰ error margin applied to the samples as per standard practice. Radiocarbon dates (reported as ^{14}C years before present, ^{14}C BP) were calibrated using OxCal 4.4 (Bronk Ramsey, 2009) with the IntCal20 calibration curve (Reimer et al., 2020). The calibrated age ranges (calibrated years before present, cal BP) are presented with 1σ (68.3 %) and 2σ (95.4 %) probability intervals. Uncalibrated ^{14}C dates include their respective 1σ errors (Table 3).

6. Discussion

6.1. *Complexity of the lithic industry*

The lithic assemblage from the oldest stratigraphic unit of Nare site provides valuable insights into raw material procurement, technological choices, tool production, and use-related activities in the region.

The data suggest a lithic industry adapted to local raw materials, balancing expedient production with elements of curated technological strategies, including core maintenance and possible tool reshaping.

However, it remains unclear whether the observed spatio-temporal fragmentation of the *chaîne opératoire* is an inherent feature of the technological system or simply results from the small sample size and limited excavation area.

6.1.1. *Raw material procurement*

The lithic assemblage at Nare demonstrates a strong reliance on locally available raw materials, primarily quartz and fine-grained chert, with no evidence of exotic materials. This suggests that tool production was entirely dependent on nearby sources, likely facilitated by the abundant chert and quartz cobbles and pebbles naturally present in the Magdalena valley and its tributaries. The ease of access to these high-quality materials likely minimized procurement efforts.

Reduction strategies focused on flaking cobbles and pebbles of chert, quartz, and, to a lesser extent, quartzite, to produce small-sized flakes. In some instances, bipolar-on-anvil percussion was employed, likely to

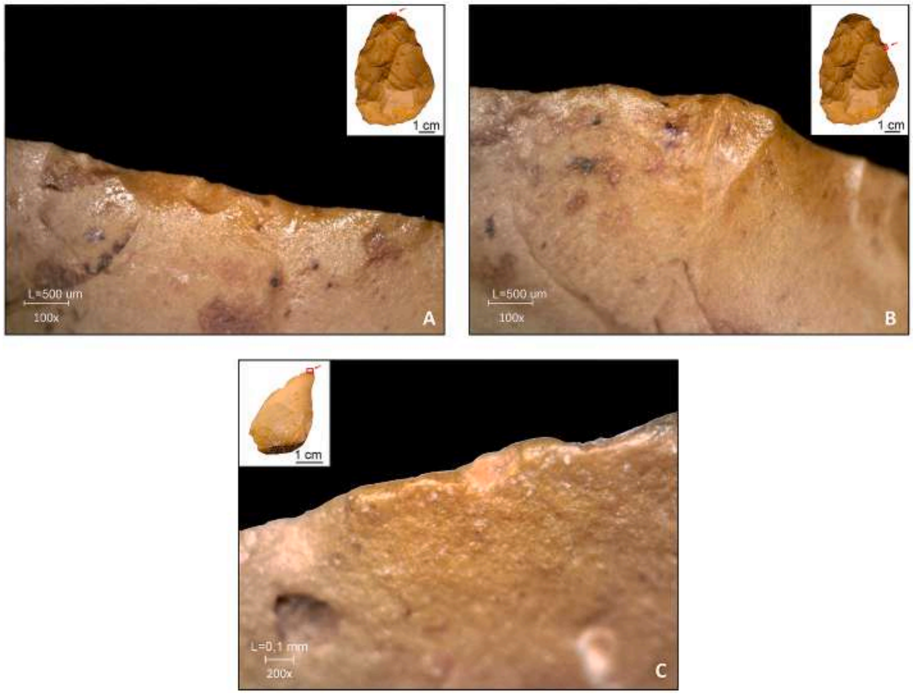

Fig. 10. a) Transversely oriented scars with feather terminations; b) intense edge rounding; c) edge rounding with small feather terminating scars; d) overlapping large step-terminating scars. (Analysis: S. Arrighi; Photo: G. Lembo).

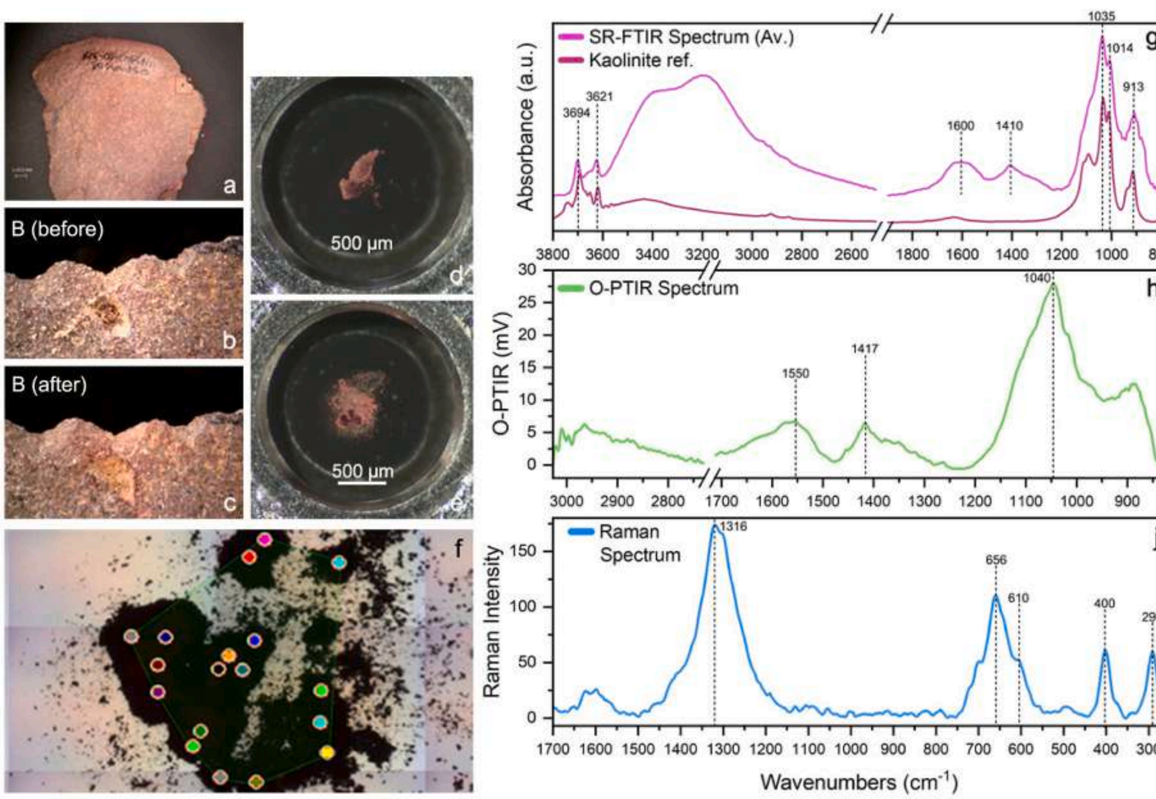

Fig. 11. (a–c) Artifact 378 (a) and close up of the dark red residue before (b) and after (c) the collection of sample 378B. (d, e) Sample 378B on the bottom window of the diamond cell, before (d) and after (e) the compression. f) Sample 378B under the VIS-IR Hyperion 3000 microscope, with the indication of the spots measured by SR-FTIR microscopy. g) Average SR-FTIR spectrum of sample 378B compared to a reference spectrum of kaolinite from the Kimmel Center for Archaeological Science Infrared Standards Library. h) O-PTIR spectrum of sample 378B, showing similar spectral features to the average SR-FTIR spectrum. j) Colocalized Raman spectrum of sample 378B with the indication of the features described in the text.

split pebbles and maximize raw material use. Despite the small sample size, chert appears to have been preferred for core preparation, flake production, and tool manufacture, likely due to its fine grain, homogeneity, and predictable fracture patterns, which offer greater knapping control. In contrast, quartz exhibits a higher proportion of broken flakes and debris, reflecting its less favorable flaking properties.

The presence of only a single unifacially shaped tool in chert raises questions about potential raw material selection for specific tool types. However, given the limited dataset, it is uncertain whether different raw materials were deliberately chosen for specific functional needs.

6.1.2. Core reduction strategies and flake production

The lithic reduction at Nare appears to have focused on producing unretouched flakes. However, the assemblage does not fully represent all reduction stages. Though some cortical flakes are present, their scarcity suggests that the earliest phases of core exploitation may have taken place elsewhere.

Flakes generally display few dorsal scars, mostly following unidirectional or orthogonal patterns. The lack of evidence for preplanned debitage methods suggests that reduction strategies were relatively expedient and flexible rather than structured. The variability in flake morphology further supports an adaptable technological approach rather than a standardized production sequence.

A notable exception is the bladelet core, which indicates an interest in producing elongated blanks.

However, the absence of bladelets in the assemblage raises questions about whether this strategy was fully implemented at the site. It is possible that the core itself was curated and transported as part of a mobile toolkit or that bladelets were produced on-site and then removed for use elsewhere. Alternatively, their absence may simply reflect the limited excavated area rather than a true lack of bladelet production.

This finding is particularly significant, as it may represent the first documented evidence of bladelet production at these latitudes in Colombia. A potential parallel exists with an isolated bladelet core found at El Abra 3 in an Early Holocene level (Muttillo et al., 2021), though further chronological and technological studies are required to establish broader regional patterns. More generally, the presence of volumetric core exploitation, even in a single specimen, is noteworthy in the South American context, where blade production is rarely reported.

Only recently blade technology was identified in early archaeological contexts in the Uruguay river basin, during the Pleistocene-Holocene transition in northern Uruguay (Suárez, 2011, 2015, 2017; Suárez et al., 2018), and during the early Holocene in southern Brazil (Batalla et al., 2018; Lourdeau et al., 2014).

Additionally, evidence of bipolar-on-anvil percussion on quartz and quartzite flakes suggests another reduction strategy aimed at splitting pebbles and maximizing raw material use. This technique is indicated by three flakes displaying opposing impact points on their ventral faces.

The coexistence of multiple reduction strategies—expedient flake production, structured core exploitation for bladelets, and bipolar percussion—highlights the technological versatility of the assemblage.

6.1.3. Tool production and function

The most formally structured implement in the assemblage is an unifacially shaped tool, produced through a sequence of flaking, shaping, and retouching.

These artifacts have been referred to by various names in the literature, including limaces or the equivalent term in portuguese lesmas (e.g., Lourdeau, 2016; Lourdeau et al., 2023), *turtle-back scrapers* (e.g., Ranere and Cooke, 2021), plano-convex scrapers (e.g., López, 1999, 2008, 2021), unifaces (e.g., Chauchat, 2022).

The term unifacially shaped tool was introduced by Lourdeau to more precisely define this category of Early Holocene artifacts of Brazil, specifically within the Itaparica technocomplex (Lourdeau, 2012, 2015, 2017; Lourdeau et al., 2023). It has since been adopted in recent literature, including within the Colombian context (González-Varas et al., 2023). We follow this terminology as it better reflects the technological processes involved in their production.

Similar tools have been identified not only in Brazil but across South America, such as Colombia (e.g., López, 2008), Ecuador (e.g., Bell, 2000), Peru (Chauchat, 2022), Paraguay (e.g., Lasheras et al., 2013), Argentina (e.g., Civalero and Nami, 2020; Nami and Civalero, 2017).

Their production appears to be linked to Pleistocene-Holocene technological traditions, making them a potential cultural marker of this period (e.g., Chauchat, 2022).

Despite variations in morphology, dimensions, environmental contexts, and the different terminologies used across South America, these artifacts correspond to the same tool type and follow a common production process, a “débitage then shaping” combination, adhering to a shared technological concept (Lourdeau, 2012). These tools were designed to support multiple rejuvenation and reshaping phases, extending their usability before eventual discard and allowing for an extended use-life (Lourdeau, 2017).

In line with this, large unifacial tools are often considered curated implements—crafted and transported for repeated use rather than discarded after a single activity (Bamforth, 1986; Binford, 1979). Some may have been part of personal toolkits, others were left at sites as furnishing tools (Binford, 1979; Nami, 2019).

At Nare, the presence of a re-sharpening flake suggests that tool maintenance may have occurred. However, it cannot be directly linked to the unifacially shaped tool, and no clear traces of re-sharpening were identified directly on the tool itself (and the uniform patina covering the entire piece further complicates this assessment). The observed retouching appears to be part of the original finishing process, though a brief re-sharpening episode following initial use cannot be ruled out.

Since this is the only artifact of its kind in the assemblage, assessing post-use modifications remains challenging. While some evidence suggests tool curation, the small sample size and the abundance of raw materials in the region make it difficult to determine whether lithic management strategies at the site were primarily curated or expedient.

Often regarded as multipurpose implements (e.g., Chauchat, 2022; González-Varas et al., 2023), the precise function of these tools remains debated, largely due to the scarcity of use-wear analyses.

In this case, use-wear analysis identified rounding and small transverse scars on the tip, suggesting probable use in processing medium to soft materials, possibly with the use of abrasive substances. The variation in thickness between the base and tip further supports an ergonomic design, with the broader base likely serving as a grip and the refined tip shaped for specific tasks.

Use-wear analysis identified functional traces on several flakes, suggesting they were likely used for cutting materials like those found on the tool.

Residue analysis allowed the identification of sample 378B as a mixture of clay minerals and iron oxides, respectively kaolinite and hematite. These minerals are commonly associated in soils from humid tropical and temperate regions (Dixon and Weed, 1989), with iron oxides frequently forming natural deposits on archaeological artifacts. In some cases, their presence has been linked to the oxidation of sulfur-rich compounds in anthropic contexts (Croft et al., 2018; Dominici et al., 2023).

The location of sample 378B on the edge of a quartzite flake may raise the possibility of the intentional use of hematite in human activities such as hide-processing—a practice well documented among both past and present human groups (Dubreuil and Grosman, 2009; Rifkin, 2011; Rosso et al., 2016; Wang et al., 2022; Watts, 2002). However, use-wear traces found on ID 378 proved to be non-diagnostic. Therefore, without further contextual data—such as local geochemical analyses, repeated occurrences of hematite residues associated with clear use-wear traces, or the finding of hematite nodules at the site—this possibility is speculative.

Moreover, the absence of faunal remains and associated archaeological materials complicates efforts to link tool use to resource exploitation. Further use-wear and residue analyses are necessary to fully exploit the potential of microscopic data and to provide more definitive insights into tool function and human activities in this region.

6.1.4. Rethinking technological interpretations

The lithic assemblage from Nare reflects a flexible technological system adapted to local raw materials. The *chaîne opératoire* suggests an efficient yet varied approach to lithic reduction, combining different methods to maximize resource use.

While previous research in the Middle Magdalena region has emphasized the presence of bifacial technology (López, 2008; López et al., 2021), the analysis of the material from the oldest stratigraphic unit at the Nare site presents a more nuanced picture. In the assemblage analyzed here, no bifacial thinning flakes or finished bifacial tools were identified. Instead, only a few retouch flakes with plain butts were recovered. It is worth noting that López (2008) reported the presence of few bifacial thinning flakes within this stratum, with their number increasing in the overlying SU 2. Moreover, bifacial tools have been found in nearby surface contexts in the region, although these derive from undated deposits. These contrasting lines of evidence may reflect spatial or functional variability in bifacial technology, or differences in site use over time.

The assemblage is primarily characterized by unifacial reduction, with a shaped tool and a bladelet core representing its most structured elements. The overall technological diversity suggests that complexity in this context may be better understood in terms of varied reduction strategies rather than formal tool types.

The assemblage indicates a combination of direct percussion with a hard hammer for general flake production and soft-hammer percussion (organic or soft stone) for shaping tools and detaching bladelets. Knapping primarily involved flaking cobbles and pebbles of chert, quartz, and quartzite to produce small to medium-sized flakes. The presence of bipolar-on-anvil percussion on quartz and quartzite indicates an additional strategy to split pebbles and maximize raw material efficiency.

A significant element in the assemblage is the bladelet core, suggesting the adoption of volumetric knapping and structured core exploitation. However, no bladelets were recovered, raising the possibility that they were transported off-site as part of curated toolkits. Alternatively, their absence could be due to the limited excavation area. The presence of this core is nonetheless noteworthy, as it may represent one of the earliest attestations of bladelet production at these latitudes in Colombia, comparable to the bladelet core identified at El Abra (Muttillo et al., 2021).

The organization of lithic production at Nare also raises questions about curation vs. expediency. Binford (1979) defines curation as a strategy for maximizing tool utility and extending use-life, particularly in contexts of raw material scarcity or high mobility. Given the abundant lithic resources in the Middle Magdalena region, technological choices at Nare were likely shaped more by mobility patterns than material constraints.

Some aspects of the assemblage suggest deliberate raw material management. The re-preparation of the striking platform on the bladelet core indicates an effort to prolong its use, a feature often linked to curated strategies. Its small size suggests it may have been transportable, possibly part of a mobile toolkit. The absence of bladelets in the assemblage further supports the idea that they were removed for use elsewhere, aligning with Binford's (1979) concept of personal gear, where tools are maintained and transported for extended use. However, the limited number of artifacts and the abundance of local materials suggest a more flexible approach rather than strict resource optimization.Another relevant aspect is recycling. The presence of a rejuvenated bladelet core, an unifacially shaped tool with possible re-sharpening traces, and retouch flakes suggests some degree of maintenance and reuse. Recycling does not always reflect intentional curation. It may also result from opportunistic reuse driven by immediate needs, a behavior typically associated with expedient technological strategies. Given the small sample size and lack of clear patterns, it remains uncertain whether these modifications reflect a structured resource management strategy or a more situational response.

Expedient strategies involve on-site tool production for immediate use, with little concern for conservation or transport. This approach is typical in contexts where raw materials are easily accessible. At Nare, the high availability of lithic resources may have favored a more flexible, short-term approach to lithic production. However, the presence of a bladelet core and evidence of core maintenance suggest that, at least in some cases, lithic reduction aimed at maximizing raw material efficiency. Blade/bladelet production is often associated with conservation strategies, as each removal produces a useable blank with a high edge-to-mass ratio (Nelson, 1991; Parry and Kelly, 1987). While blade production is generally linked to curated technologies, the absence of bladelets complicates this interpretation.

The lithic industry at Nare does not fit neatly into a strictly curated or expedient model. Instead, the data suggest a flexible technological approach, where different strategies—some curated, others expedient—were applied based on specific needs and mobility patterns. The limited artifact count, and small excavation area make it difficult to determine whether raw material exploitation was primarily opportunistic or involved sustained curation. However, the presence of core maintenance, an unifacially shaped tool, and structured bladelet production indicates that at least some aspects of the assemblage reflect intentional planning rather than purely expedient behavior.

6.1.5. Interregional relationships

Reconstructing early human settlement in Colombia requires examining the relationships between lithic industries from different regions, as these provide essential clues to patterns of mobility, interaction, and technological transmission. Among these regions, the Middle Magdalena Valley and the Sabana de Bogotá region, in the Cundiboyacense High Plateau (Eastern Cordillera), hold particular significance. Their contrasting yet interconnected environments—the inter-Andean lowlands and the highland plateau—may have played complementary roles during the Pleistocene–Holocene transition, shaping the dynamics of early human dispersal across northern South America.

Traditionally, the Middle Magdalena Valley has been regarded as a favorable corridor that may have facilitated human movements between the tropical lowlands and the Andean highlands (e.g., Aceituno et al., 2013; Delgado et al., 2015; López, 1998, 2008, 2021; Ranere and López, 2007), particularly toward the Cundiboyacense High Plateau— the most extensively studied region and the richest in sites dated to the Pleistocene–Holocene transition, including Tibitó, Tequendama, and El Abra (e.g., Correal, 1982, 1990; Correal et al., 1969; Hurt et al., 1977).

A possible cultural and mobility connection between these two regions was first hypothesized by Correal and van der Hammen (1977), based on seven retouched tools recovered from the lower levels of the Tequendama I rock shelter (Zone I, dated to 11,000–10,000 uncal BP). Three of these artifacts were made on exogenous raw materials, interpreted as originating from the Magdalena Valley. Despite their small number, these artifacts were used to define the so-called *Tequendamiense* tradition (Correal, 1982, 1990; Correal and van der Hammen, 1977).

These pieces stand out within the assemblage for their more elaborate workmanship, produced by controlled percussion and/or pressure flaking on fine-grained, partly non-local raw materials (Correal, 1982, 1990; Correal and van der Hammen, 1977; Hurt et al., 1977). This contrasts with the *Abriense* tradition, named after the eponymous El Abra site, which dominated most Sabana de Bogotá assemblages from the Late Pleistocene onward. The *Abriense* industry, or "edge-trimmed tool tradition," represents an expedient unifacial technology characterized by cores, flakes, and a limited number of tools made from locally available raw materials. It is generally considered to span a long chronological range, from about 12,400 uncal BP to historical times, with no apparent technological variation throughout this period. The presence of the three exotic bifacial artifacts at Tequendama was therefore interpreted by Correal as evidence of seasonal mobility between the Magdalena Valley—considered the lithic production area—and the Cundiboyacense Plateau, where these tools were used (Correal, 1990; Correal and van der Hammen, 1977). Nevertheless, this hypothesis has never been systematically tested. No detailed technological, raw material, or provenance analyses have been conducted to confirm or refute a connection with the Magdalena Valley. At present, there is no solid evidence—neither artefactual nor faunal—indicating direct contact between the two regions (Nieuwenhuis, 2002).

As López (2008:146) observed, "the small number of tools from the Sabana de Bogotá used to define the *Tequendamiense* assemblage is almost certainly only a subset of a bigger and more complex lithic tradition found in the inter-Andean lowlands; the Middle Magdalena is the most likely home for this tradition." The *Abriense–Tequendamiense* dichotomy has never been fully revisited or resolved in Colombian archaeology, although several scholars have expressed criticism toward its continued use (López, 2008; Nieuwenhuis, 2002). Above all, the extrapolation of these categories beyond their original context—to different regions, periods, and technologies—introduces substantial analytical and interpretative complications (López, 2008).

This debate has gained renewed relevance considering recent reevaluations of key sites in the Sabana de Bogotá, which have reassessed the chronological and stratigraphic integrity of the classical sequences underlying these traditional classifications and questioned their technological and cultural meaning. These studies—particularly at El Abra and Tibitó—underscore the need for comprehensive reassessment, including verification of stratigraphic integrity, reanalysis of artifact assemblages, and the integration of techno-economic and functional perspectives (Muttillo et al., 2017, 2019, 2021). At Tibitó, most lithics have been identified as geofacts rather than intentionally modified artifacts (Muttillo et al., 2017, 2019), while at El Abra, the earliest unit contains few Late Pleistocene dates of questionable reliability (Delgado et al., 2015) and no associated artifacts (Muttillo et al., 2021). The Early Holocene assemblage at El Abra—still requiring further chronological refinement—represents a core-and-flake industry with a limited number of unifacially retouched tools made from local raw materials. Notably, the presence of a bladelet core challenges the idea of a purely expedient industry and calls into question the technological homogeneity of the so-called *Abriense* tradition (Muttillo et al., 2021).

Considering these issues, any comparison between lithic industries from the Middle Magdalena and the Sabana de Bogotá remains preliminary and must be approached with great caution. Our understanding of early lithic technologies and settlement dynamics in both regions is still incomplete. Without systematic re-evaluation and updated chronological frameworks, interregional comparisons will remain speculative and potentially misleading.

Continued research, reanalysis of legacy collections, and the discovery of new sites through modern methodologies are therefore essential to reconstruct early mobility systems and to evaluate the potential role of the Middle Magdalena Valley as a key corridor linking Colombia's diverse environmental zones.

6.2. *Interpretation of the radiocarbon dates from Nare: a more refined chronology*

The new radiocarbon dates from the Nare site provide a more detailed chronological framework, extending the known timeframe of occupation and confirming human presence throughout the Early Holocene, nearly reaching the transition to the Middle Holocene.

A key refinement is the closure of a previous chronological gap (~12,500–5900 cal yr BP). The new dates confirm occupations from ~11,000 to ~8000 cal yr BP, reinforcing the integrity of the site's stratigraphic sequence.

The comparison between the new radiocarbon dates and those obtained in the early 2000s reveals a broadly consistent chronological framework for stratigraphic unit 3. The earlier dates fall close to the Pleistocene/Holocene boundary (ca. 12,600–11,900 cal BP), whereas the oldest of the new dates is slightly more recent, at approximately 11,200 cal BP. The remaining new dates fall between 9300 and 7900 cal BP. Although the calibrated ranges do not entirely overlap at the 95.4 % confidence level, their stratigraphic positions support chronological consistency. This pattern may reflect a gradual accumulation process or minor post-depositional disturbances. Overall, the results confirm the reliability of both sets of dates and support a prolonged Early Holocene occupation of the site.

7. Conclusions

The Nare site provides valuable insights into the technological and adaptive strategies of early human groups in Colombia. The updated chronological framework, together with a reassessment of the site's earliest lithic industry, highlights the diversity and sophistication of flint knapping practices in the Middle Magdalena region.

Chronologically, the new radiocarbon dates place the site's occupation firmly within the Early Holocene, extending into its later phases and approaching the Middle Holocene threshold. This temporal span reinforces the site's role as a location of long-term or recurrent use.

The evidence suggests a flexible and efficient approach to raw material exploitation, marked by varied debitage methods and knapping techniques. Notably, the presence of a bladelet core points to the adoption of a technological innovation often associated with greater productivity and versatility. The absence of bladelets themselves raises important questions about off-site tool use and mobility.

In addition, the recovery of an unifacially shaped tool and several retouch/resharpening flakes supports the notion of a dynamic toolkit that balanced expedient production with curated maintenance strategies.

These findings align with emerging perspectives that view Early Holocene populations as highly adaptable groups capable of diverse technological solutions.

The reassessment of Nare enriches our understanding of early cultural variability in northern South America and offers a nuanced perspective on early human adaptations in the region. Its archaeological record stands as an important reference point for understanding prehistoric settlement dynamics and technological organization across the northern Andes and adjacent lowlands.

Future research should aim to refine this regional picture through expanded excavation, residue and use-wear analyses, and comparative studies with other contemporaneous sites in Colombia and beyond. This will help clarify the role of bladelet technology, mobility strategies, and broader cultural affiliations.

CRediT authorship contribution statement

Brunella Muttillo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Giuseppe Lembo:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Sahra Talamo:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **Laura Tassoni:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **Simona Arrighi:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **Clarissa Dominici:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **Chiaramaria Stani:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **Martha Cecilia Cano:** Writing – review

& editing, Validation, Investigation, Formal analysis. **Carlos López:** Writing – review & editing, Validation, Investigation, Formal analysis.

Declaration of competing interest

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

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