# Investigating non-flint lithic resources management during the Upper Palaeolithic in the Aquitaine Basin using an integrated approach: A Late Solutrean case application (Landry, Dordogne, France)

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**Abstract:**

As opposed to areas with a crystalline substratum, the Aquitaine Basin in southwestern France is a territory where flint and chert resources are abundant. The exploitation of those cryptocrystalline, silica materials prevailed in this region throughout prehistory, especially during the Upper Palaeolithic, but other rock types frequently account for a noticeable proportion of the archaeological record. In such context, the choice to rely partly on non-flint lithic materials cannot be seen as an alternative strategy to compensate for an absence of flint. However, poor documentation is currently available for discussing the economic role of these resources.

We take here the example of Landry, an open-air site in the Isle Valley showing a single occupation level providing mobile art and characteristic Late Solutrean (24-23 ka cal. BP) flint productions. This site yielded non-flint lithic remains in considerable number, some of which related to flake production or macro-lithic implements. The documentation of this component was considered essential, both to understand the site in a more comprehensive way and to provide first insights into the economic role of such resources in the Late Solutrean.

In order to explore several phases of the exploitation of non-flint lithic resources (thus leading to a comprehensive documentation of this component), we relied on a set of complementary methodologies classical for lithic analysis but adapted to the peculiarities of non-flint rocks according

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to recent developments of the field. Determination of raw material lithology and procurement areas was achieved through a petrographic analysis (macro and mesoscopic scales) coupled with a field survey. A technological analysis led to the identification of blank production methods and objectives. An observation of macroscopic use-wear traces coupled with an analysis of techno-functional units allowed a first approach of tool diversity, especially concerning non-manufactured tools. Edged tools were further investigated through a use-wear study (Low and High Power Analyses). Analysis of the planimetric distribution of non-flint lithic artefacts revealed the spatial organisation of related processes and activities.

At Landry, non-flint raw materials relate to a wide petrographic spectrum (quartz-quartzite, dolerite, ignimbrite, etc.) originating from local alluvial deposits. Edged tools result from short flaking production sequences (unmodified flakes) or partial shaping (worked pebbles), while non-manufactured blanks (pebbles, fragments) constitutes a multi-purpose toolkit (percussion, friction, work surfaces, etc.). Blank production or selection occurred on the spot, as the need arose. By comparing these results with available data on the flint component, this study reveals the complementarity between a highly mobile flint toolkit (anticipating future needs) and a local expedient but diversified toolkit (for immediate requirements). This dichotomy goes beyond the flint versus non-flint duality.

Despite some limitations, the approach presented in this paper gives a global and integrated vision of the processes related to non-flint lithic resources exploitation at the site, allowing comparison and combination with other available data (*e.g.*, flint production) and preparing additional analyses.

**Keywords:** Late Solutrean; Aquitaine Basin; non-flint lithic resources; petrography; lithic technology; techno-functional units; spatial distribution

## 1. Introduction

After an initial and long-lasting interest in the establishment of a chronological sequence of prehistoric artefacts and cultures, Palaeolithic archaeology now focuses more and more on questioning past societies and lifeways, thus initiating what one can call a "palethnographic" approach (*e.g.*, Leroi-Gourhan & Brézillon 1972: 257-261; Pigeot 2004: 255), complementary to the "stratigraphic" one. Considering the archaeological archives as an indirect and partial record of original activities, such an approach must draw on all available data in order to render prehistoric behaviours as accurately as possible.

However, our discipline historically focused on few specific remains considered to be the most relevant ones, notably under the influence of other paradigms (*i.e.*, "fossils-directors"). The renewal of our interest in other components of the archaeological record is in progress, benefitting from technical and methodological innovations, but some gaps remain. As an example, despite several pioneering studies (*e.g.*, Aubry 1991: 115-121; de Beaune 1989; 1993; 2000; Bosinski & Guicharnaud 2008; Bracco 1993; 1997; Dubreuil 1996; Llana & Villar 1996; Straus 1996; Zilhão 1996), little is known about non-flint stone exploitation during the Upper Palaeolithic in western Europe, especially in flint-rich regions like the Aquitaine Basin.

In nearby crystalline areas (*e.g.*, Massif Central, Cantabrian Mountains), the scarcity of flint outcrops forced Upper Palaeolithic people to rely on long-range circulation systems or on local non-flint resources (*e.g.*, Bracco 1996; Delvigne *et al.* 2019; Prieto *et al.* 2021). On the contrary, the Aquitaine Basin is a sedimentary region with relatively considerable quantities of flint and flint-like resources (*e.g.*, Morala 2017; Séronie-Vivien & Séronie-Vivien 1987; Turq & Morala 2013). However, Upper Palaeolithic people in this area also used other lithic materials, which often represent a substantial part of lithic assemblages. The questions linked to these resources are thus different from those arising in crystalline regions. Considering the Upper Palaeolithic settlement in the Aquitaine Basin, non-flint resources could not be substitution materials offsetting a deficiency of flint resources. More likely, they played a specific role in hunter-gatherer economy, presumably interacting with other resources (flint, bone, pigments, etc.) and completing them. Despite this, data regarding this topic are yet too scarce and imprecise to clarify this question.

As part of doctoral work investigating non-flint lithic resources management during the Solutrean-Badegoulian transition in the Aquitaine Basin, we first investigated this question through the study of the non-flint lithic assemblage from the Late Solutrean open-air site of Landry (Dordogne, France). This study represents an early step towards the documentation of non-flint lithic resources management in this chrono-cultural and geographical context. With this in mind, we opted for a global investigation of this component, tackling several of its main aspects (raw material procurement, production systems, tool diversity, patterns of spatial organisation, etc.). This paper aims to present the methodological approach that we used, supported by this case application. More detailed results are available (in French) both in the Ph.D. dissertation (Villeneuve 2023) and in the site monograph (Brenet *et al.* 2025).

## 2. The Late Solutrean open-air site of Landry

The site of Landry (Boulazac-Isle-Manoire, Dordogne, France) was the object of a rescue excavation by the French National Institute for Preventive Archaeological Research (INRAP) between 2011 and 2012, under the direction of one of us (M.B.). Post-excavation studies (Brenet 2014) highlighted the importance of the site in the understanding of the Late Solutrean, motivating a multi-disciplinary research project (Brenet *et al.* 2018), which includes our work on the non-flint lithic series. This project resulted in a monograph publication (Brenet *et al.* 2025).

Located on a terrace on the left shore of the Isle River (Figure 1), this open-air site provided only lithic remains (about 13,000 for a total weight of more than a ton) since organic materials were not preserved (Brenet 2014: 35-50). Geo-archaeological analyses indicate that the site was rapidly covered by silts deposits, ensuring its preservation. The only significant disturbance is a solifluction channel in the north-westernmost sector, which resulted in the formation of two distinct archaeological layers (Bertran *et al.* in Brenet 2014: 51-67), while there is only one in the rest of the site. Analysis and refitting of flint remains confirms the existence of a single archaeological level, coherent both in terms of technology and typology (Bertran 2025). It is organized around five main artefact clusters, possibly corresponding to distinct activity areas (Figure 2; Brenet *et al.* 2017).

Most of the flint component refers to local (< 5 km) flints varieties of variable quality, only associated with a few finished or recycled tools made from good quality resources of distant origins (up to 300 km; Delvigne 2025). Distinct reduction methods provided blades, bladelets and flakes, which constitute the blanks of various common Upper Palaeolithic tools (*e.g.*, endscrapers, burins, borers, splintered pieces; Figure 3A, n° 1 to 11). In addition, preforms and broken pieces attest the shaping of characteristic Late Solutrean lithic implements such as laurel leaf points and shouldered points (Figure 3A, n° 12 to 16; Bachellerie 2017: 17-43; Brenet *et al.* 2018: 45-122). Use-wear analyses of flint tools suggest a wide diversity of activities, such as hunting, meat preparation or hide working (Claud & Mesa in Brenet *et al.* 2018: 123-157).

In addition to this, non-flint lithic remains form a substantial part of the assemblage (17% of collected objects, more than 85% of total weight). A preliminary analysis (Brenet in Brenet 2014: 191-218) revealed the potential of this assemblage showing evidence of flaking, partial shaping and use as percussive tools (hammers, anvils). Since then, some specific features of this series were investigated, such as blocks with figurative or geometrical engravings (Figures 3B and 3C) (Feruglio *et al.* 2016), grooved blocks related to passive use in association with cutting implements (Mesa-Saborido 2016: 48) and lustrous gravels related to unidentified anthropic activities (Geis 2018: 56-57; Geis *et al*. 2023). But the main technological features of this series as well as their economic implications compared to the flint component still needed a dedicated analysis.

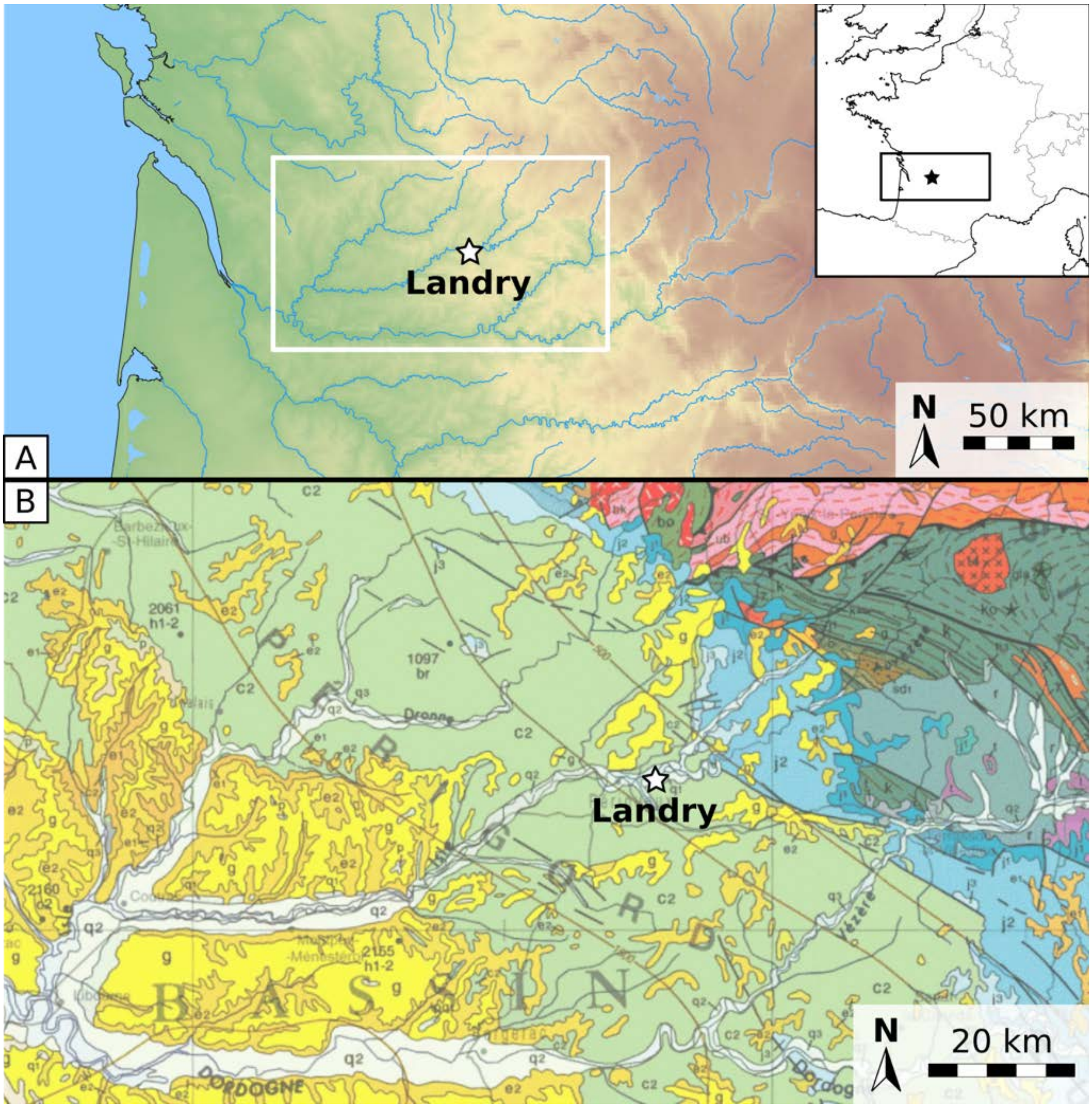


Figure 1. A: Location of the site in the middle valley of the Isle River, in southwestern France (elevation map from European Environment Agency). The white rectangle shows the extent of map B. B: The site in its geological context, at the north-eastern margin of the Aquitaine Basin (map base from BRGM).

## 3. Materials and methods

The non-flint lithic assemblage from Landry is large (N = 2224) and diversified. Our objective was to document it in a way that would allow its comparison with the associated flint assemblage, thus building a comprehensive interpretation of the site. This implied investigating several features (origins and procurement of the raw materials, methods and objectives of blank production, tool diversity and use, patterns of spatial distribution), then binding the results in a dynamic reconstruction of past activities, following the concept of the *Chaîne opératoire*.

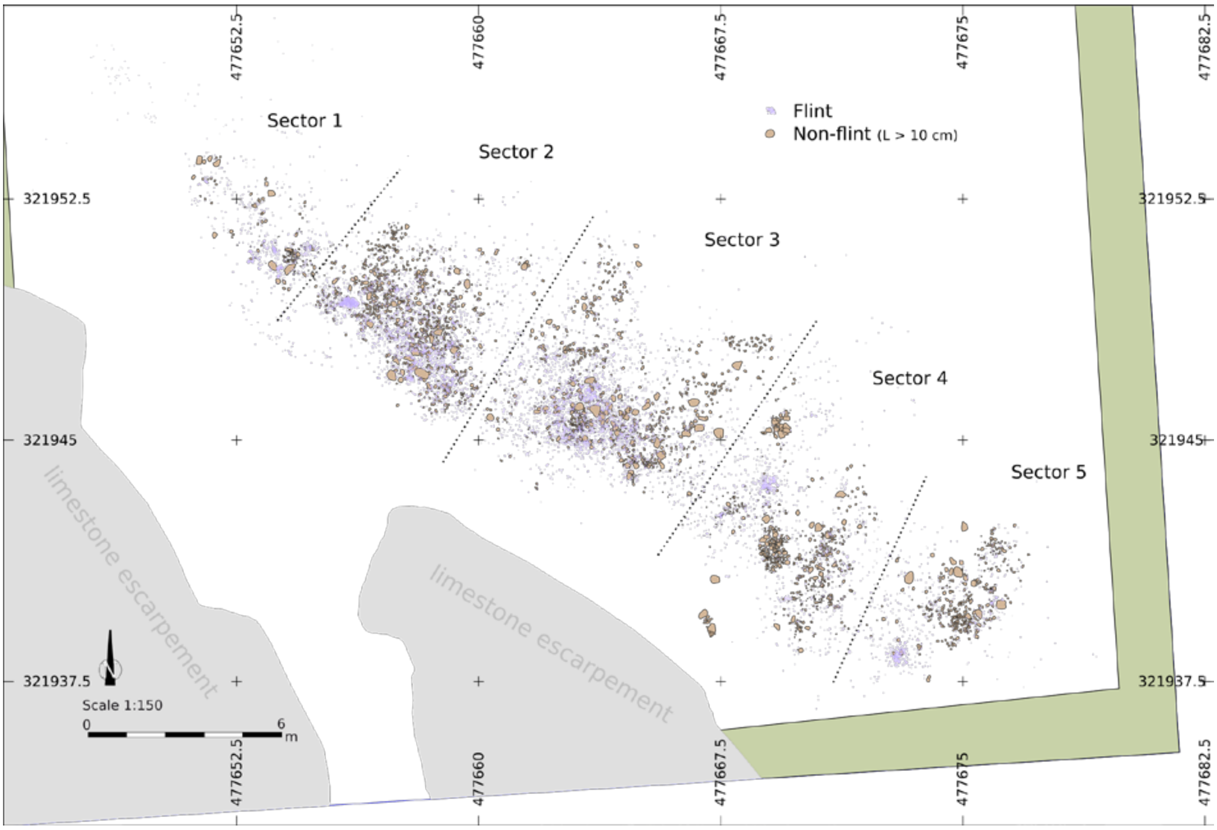


Figure 2. Spatial distribution of artefacts showing the five clusters (sectors) that form the archaeological level (illustration V. Pasquet & Q. Villeneuve).

A *chaîne opératoire* can be defined as a sequence of jointed technical operations belonging to the same process and participating to the same result or goal (Balfet 1991). This concept furnishes a framework in which archaeological remains (which are intermediate or final products, intended or not, obtained along a process) can be organized and linked together, reconstructing the corresponding sequence of gestures, tasks, phases, *etc*. It allows to overcome the objects (material level) and to analyse the processes (dynamic level) and even the knowledge and choices (cognitive level) behind it (*e.g.*, Bleed 2001; Bodu 2001; Pelegrin *et al.* 1988; for a critique, see Pesesse 2019). Following several authors (*e.g.*, Bodu 2001; Sellet 1993), we distinguish four main phases in the sequence that occur from the introduction of lithic resources in the technical system to their rejection out of it: 1) raw material procurement, 2) tool manufacture, 3) tool consumption (*i.e.*, use) and 4) abandon.

We used a set of complementary analyses (petrography, lithic technology, analysis of techno-functional units, use-wear analysis and analysis of spatial distribution), each investigating one or several of these phases. In this way, the study concerns all major aspects of non-flint lithic resources management, replaced within their spatial (and temporal) dimension (Figure 4). Most of these analyses are classical for the study of flint remains, but some benefits from recent adaptations to non-flint lithic remains (detailed below).

The goal of our study was to determine the main features of the Landry assemblage, in order to compare it with other assemblages to draw a first overview of non-flint lithic resources management in the context of the Late Solutrean in the Aquitaine basin (Villeneuve 2023). This approach focusing on the big picture is a necessary step towards the identification of more specific questions, at local (site) or regional scales, that will guide future research on the subject. In this respect, other complementary analyses, especially destructive (*e.g.*, thin section petrography) or time-consuming ones (*e.g.*, functional analyses lacking reference material), were not performed, despite their value for the investigation of specific questions, some of which related to the peculiarities of Landry's assemblage.


Figure 3. A: Selected flint tools: borers used on hard organic material (1-3), splintered pieces used as intermediate tools (4-6), burins on blades (7-9), endscrapers on blades used in hide working (10, 11), shouldered points broken during manufacture (12) or use (13), laurel leaf points broken during repair (14) or manufacture (15, 16) (drawings P. Rouzo, Inrap). B: Refitted schist slab with engraved figurative decoration (mammoth) (photos and tracing V. Feruglio). C: Dolerite block with incised geometric decoration (photos M. Brenet, tracing V. Feruglio, photogrammetry M. Caubraque). A reproduced from Brenet *et al.* (2017); B and C reproduced from Feruglio *et al.* (2016).

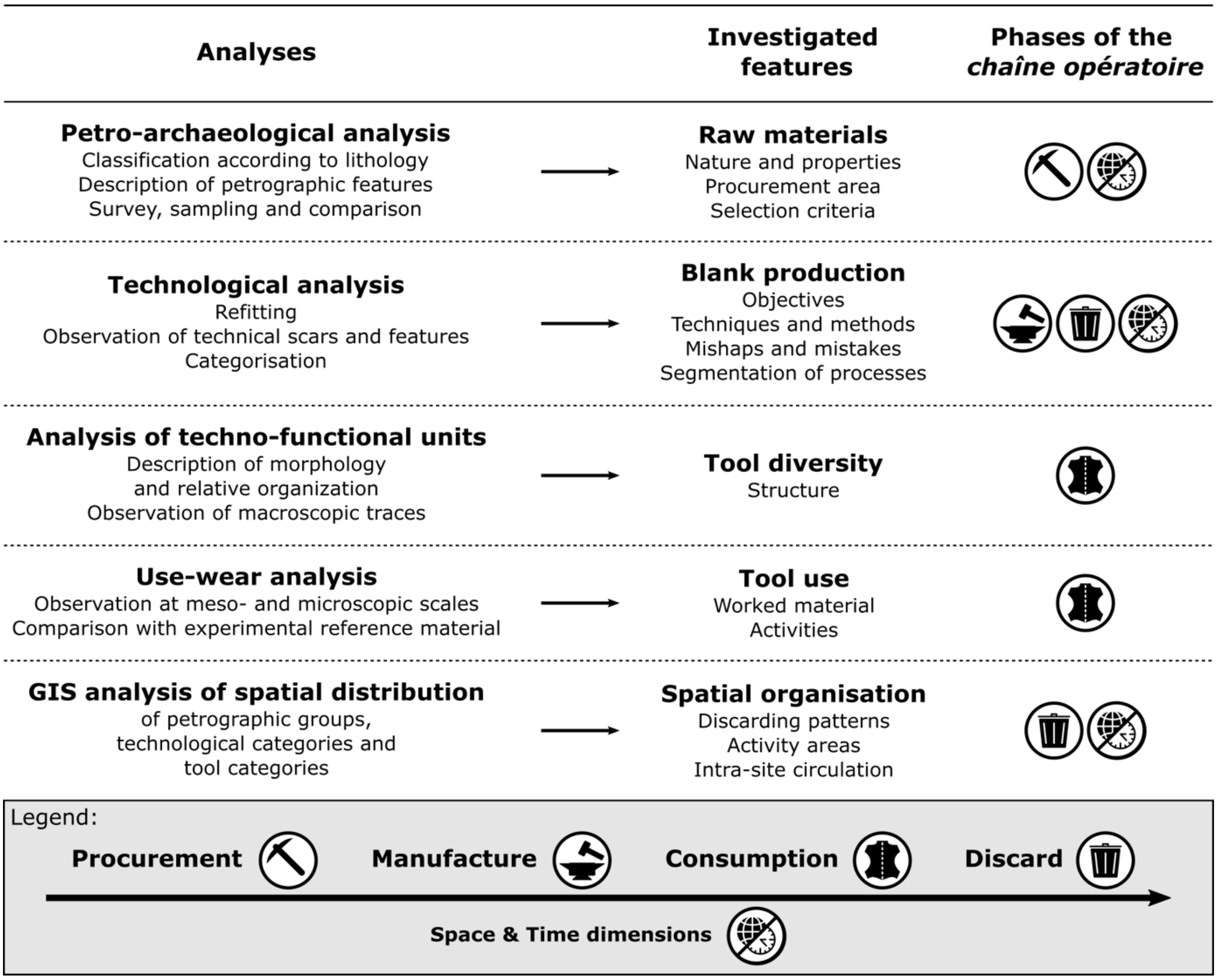

Figure 4. Synthetic scheme of the methodological approach presented in this article.

Most analyses were performed on the whole assemblage (N = 2224), or on all relevant pieces (Table 1). However, considering the high number of artefacts, some aspects of the study focused on a sample limited to the pieces found in sector 3 (N = 786; 35.3%), or on all relevant pieces from this sample (Table 1).

Table 1. Number and description of artefacts included in each analysis.

| Analyses | Pieces included | | Precisions |
|---|---|---|---|
| **Petro-archaeological analysis** | | | |
| classification according to lithology | 2224 | 100.0% | whole non-flint lithic assemblage |
| description of petrographic features | 786 | 35.3% | pieces from sector 3 |
| **Technological analysis** | 2224 | 100.0% | whole non-flint lithic assemblage |
| with a focus on knapped pieces | 186 | 8.4% | flakes and matrices |
| **Analysis of techno-functional units** | 219 | 9.8% | identified tool blanks |
| manufactured tool blanks | 64 | 2.9% | identified among all knapping products |
| non-manufactured tool blanks | 138 | 6.2% | identified among pieces from sector 3 |
| | 17 | 0.8% | identified from post-excavation preliminary analysis |
| **Use-wear analysis** | | | |
| Low Power Analysis | 63 | 2.8% | knapping products with potential use-related traces |
| High Power Analysis | 44 | 2.0% | tools with clear traces identified at mesoscopic scale |
| **GIS analysis of spatial distribution** | 2224 | 100.0% | whole non-flint lithic assemblage |

### 3.1. Investigating raw material procurement through petro-archaeological analysis

Petrographic analysis consisted of a classification of the artefacts based on their lithology (mineralogy, grain size, fabric, texture), observed with the naked eye or with stereo microscopes (Olympus SZ30, up to 40x zoom range, and Leica EZ4, up to 35x zoom range). An extensive online repository was used as reference (Lithothèque ENS de Lyon: Pinton s.d.).

Due to the diagenetic and metamorphic processes that gradually transforms a quartz-rich protolith (*e.g.*, quartz arenite, xenomorphic quartz) into orthoquartzite and then metaquartzites of increasing grade, the distinction between different types of quartzite is often difficult, even at the microscopic scale (*e.g.*, Ebright 1987; Howard 2005; Prieto *et al.* 2019; 2020). Moreover, even the eye distinction between quartzite and vein quartz can be tricky in certain cases (Mourre 1997). For these reasons, we choose to group these rocks in an undifferentiated "quartz-quartzite" category, despite occasional precise determinations.

More than its exact lithology, the mechanical properties of a rock have a direct impact on its technical capacities. Regarding knapping, fracture predictability and control are dependent on the homogeneity and isotropy of the rock exploited (Llana & Villar 1996; de Lombera Hermida 2008; 2009; Seong 2004). These properties are themselves dependent on a number of petrographic features, of which we documented the following:

- average grain size, roughly estimated using the following classes: very coarse-grained (> 2 mm), coarse-grained (1-2 mm), slightly coarse-grained (0.5-1 mm), fine-grained (< 0.5 mm, still distinguished with the naked eye), very fine-grained (only distinguished with a stereo microscope), undifferentiated (not distinguished with a stereo microscope at 40x zoom);
- average rock fabric (*i.e.*, orientation of constitutive elements): isotropic (no preferential direction), linear (oriented along a single direction), planar (oriented along a plane), plano-linear (combination of both);
- nature of structural weaknesses (if any): joints, veins, inclusions, fossils, etc.

Once the lithology and petrographic features of the raw materials are determined, it is possible to question their geological origin. Opposite to flint-like materials, for which exhaustive repositories allows detailed analysis of procurement areas and circulation routes (*e.g.*, Caux 2015; Delvigne 2016; Demars 1982; Fernandes *et al.* 2013; Geneste 1991; Vaissié 2021), the repartition of other rock types in a given region of France is often imprecise and the available repositories are not sufficient to identify local varieties. In order to search for potential procurement areas, we first relied on the aspect of external surfaces (*i.e.*, other than fracture facets) to make the distinction between raw materials acquired in alluvial or non-alluvial deposits (respectively bearing well-rounded or poorly-rounded external surfaces). Following this, we carried out a walking survey in the site's surrounding formations, followed by the sampling of the Upper Pleistocene terrace identified as a potential catchment deposit. The sampling concerned the superficial layer of a recently ploughed plot (about 250 m²) and followed the same methodology as the one used at the site for plotted non-flint remains (only taking the objects longer than 5 cm, with the exception of limestone whose presence at the site is natural). We compared this sample (N = 424; 83 kg) with the archaeological assemblage, both to control their likeliness and to determine selection patterns. Of course, a single sample only gives a first idea, as systematic surveys and samplings would be needed in order to approach the inner variability of the deposit. This comparison concerned the lithology and above-mentioned petrographic features as well as the size and shape of the volumes, considering that these features could also act as selection criteria. Assessing the latter two in the archaeological assemblage was only possible with non-fractured or sub-complete volumes, which induces a bias as fractured volumes are not considered (except through refitting). The shape was roughly classified between rounded (no or only obtuse edges), parallelepipedal (with sub-parallel surfaces and sub-perpendicular edges), angular (with acute edges), flat (with two sub-parallel surfaces and low thickness) and irregular (not falling into the previous categories). These categories are schematic and reductive but appear operative in the identification of selection patterns concerning different kinds of exploitation. No matter the shape of the volume, its length, width and thickness correspond respectively to its axis of maximum elongation and the orthogonal intermediate and minor axes.

### 3.2. Investigating blank production through technological analysis

Traditional technological analyses (Inizan *et al.* 1999; Tixier 1978; 2012) rely on a complex observation of every artefact (taken both separately and as a whole), often associated with experimental replication and refitting. They aim to identify the objectives of blank production (result desired) as well as the techniques and methods implemented to obtain them. Analysis of each artefact focuses successively or simultaneously on a syncretic perception of the object and on a detailed observation of technical scars and morphologies (Inizan *et al.* 1999: 16; Tixier 1978: 67-69; 2012: 122-124), which lead to the understanding of the successive modifications recorded on the artefact (succession of removals, breaks, impact marks, *etc.*) and related intents (original production, maintenance, recycling, *etc.*).

If knapping scars observed on flint are well known (*e.g.*, percussion bulb, ripples, hackles; Inizan *et al.* 1999: 33-34), they are often of limited use when facing non-cryptocrystalline lithic materials, making the technological reading of the latter tricky. Since the 1990s, several published experimental studies have identified other knapping scars, mainly on automorphic or xenomorphic quartz (*e.g.*, radial and concentric fissures, step and hinge terminations; Knight 1991; de Lombera Hermida 2009; Mourre 1996b). Other common lithic raw materials show knapping scars and features related to those observed for quartz or for flint (*e.g.*, Huet 2006: 86-122). In this respect, our technological reading mainly relied on these experimental works and the illustrations they provide. It also takes advantage of the empirical knowledge provided by individual practice of stone knapping on diverse flint-like and non-flint lithic raw materials (with which several of us are familiar).

As a preliminary to the technological analysis, we carried out an extensive search for refits, following a fine sorting of the artefacts based on lithology, mineral composition, texture, fabric and colour. The refits identified were of great support for the technological analysis of the assemblage as they allowed a better understanding of fracture initiation and development and a better identification of knapping mishaps and mistakes. Following this search for refits and the observation of technical scars, we classified the artefacts in a restricted number of technological categories, inspired by the Logical Analytical System (Carbonell & Rodríguez 2002). In order to standardise the observations and to quantify them through frequency distributions or other descriptive statistics, we also documented the presence and variability of a number of technological features, depending on the category (Table 2).

### 3.3. Investigating tool diversity and use through analysis of techno-functional units and use-wear analysis

In order to quantify (through frequency distributions) the diversity and variability of the tools observed in the assemblage, we grouped them into categories based on 1) the type of macroscopic use-wear traces, following published works (Adams *et al.* 2009; Claud *et al.* 2019; Cuartero & Bourguignon 2022), and 2) the morphology and relative organisation of the active (bearing the traces) and non-active parts of the artefacts, following the concept of techno-functional units (Lepot 1993; Brenet 1996; Boëda 2001; 2013).

Table 2. List of documented technological features, according to technological category.

| Technological features (by order of examination) | Matrices (shaped or flaked items) | Flakes | | Debris | Non-fractured objects |
|---|---|---|---|---|---|
| | | Complete | Fragments | | |
| Type of fragment (proximal, distal, *etc*.) | - | - | yes | - | - |
| Proportion of external (non-fracture) surface | presence or absence | on the dorsal face (retouch not taken into account) | | presence or absence | - |
| Type of knapping mishaps or mistakes | if relevant | if relevant | if relevant | if relevant | - |
| Type of butt | - | yes | if possible | - | - |
| Flaking angle (°) | - | yes | if possible | - | - |
| Type of counter-blow surface | - | if relevant | | - | - |
| Position and type of back | - | if relevant | | - | - |
| Original blank (pebble, flake, *etc*.) | if possible | - | - | - | - |
| Development of exploitation | test, partial or total | - | - | - | - |
| Number and orientation of negatives | on each flaking surface | on the dorsal face (retouch not taken into account) | | - | - |
| Type of striking platform | yes | - | - | - | - |
| Type of percussion (hard or soft hammer) | if possible | if possible | | - | - |
| Type of reduction (freehand or on anvil) | if possible | if possible | | - | - |
| Operative theme (shaping, flaking, *etc*.) | if possible | if possible | | - | - |
| Operative scheme (centripetal, unipolar, *etc*.) | if possible | if possible | | - | - |
| Type of macro use-wear traces | if relevant | if relevant | if relevant | if relevant | if relevant |
| Dimensions (mm) | morphological axes | technological axes | size class (1 cm interval) | size class (1 cm interval) | morphological axes |
| Weight (g) | yes | yes | yes | yes | yes |

Techno-functional units are parts of an object bearing distinctive and homogeneous functional capacities (Donnart 2010). They constitute the tool's structure, *i.e.*, its internal components and its interfaces with its technical environment (*e.g.*, worker, worked material; Sigaut 1991). A tool is defined by at least two techno-functional units, the nature of which differs for active, intermediary or passive implements (Figure 5). Three types of techno-functional units are recognised for active implements (*e.g.*, Donnart 2010). The grip contact is the part held by the worker (either directly or indirectly through hafting). The receptive contact is the part that receive the energy of the worker, thus frequently overlapping the grip contact. The transformative contact is the part that transmits the energy into the worked material, modifying it. Concerning passive implements, we considered a fourth type, the resting contact, which is the part in contact with the substrate (*e.g.*, ground) that assures the balance of the tool during use.

The analysis concerned only complete tools, identified by a preliminary observation of all knapping products and of all artefacts from sector 3 regardless their technological category (plus a few tools identified during post-excavation analysis; Table 1). For artefacts bearing traces of distinct episodes of use (*e.g.*, multipurpose), each episode was considered separately (resulting in several "tools" on the same tool blank, used successively or alternatively: Boëda 2001). For each tool, we documented the morphology of the techno-functional units, their modification by manufacturing processes and their relative position on the pieces, as well as the associated macroscopic use-wear traces (type and location).

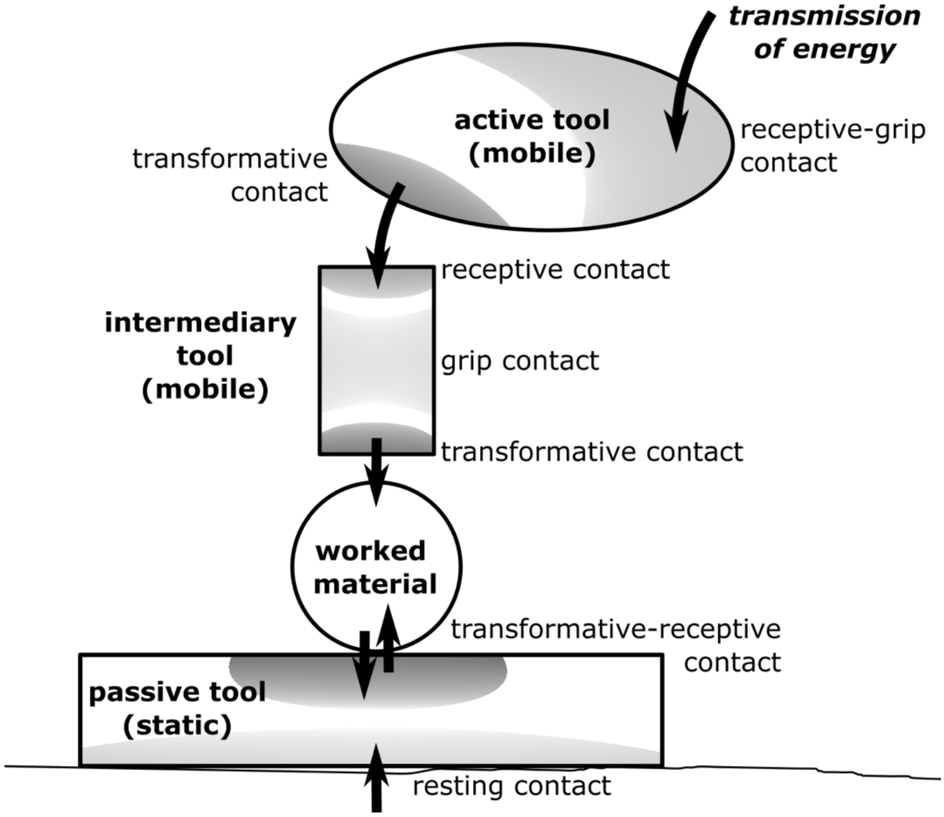


Figure 5. Schematic representation of techno-functional units on active, intermediary and passive tools.

However, this approach do not gives access to the function of the tools, which corresponds to the product of their use, *i.e.*, the relationships between them and their technical environment (*e.g.*, motion, objective and circumstances of use; Sigaut 1991). This can only be addressed through use-wear or residue analysis relying on experimental or ethnographic reference material (necessary in order to determine at least a part of the technical environment of the tools). This approach was not part of the doctoral work (Villeneuve 2023) but was led concurrently (under the direction of É.C.) as part of the monograph project. In the scope of this article, we will only present some of the results obtained, considering their complementarity with our own results. All details regarding this use-wear analysis are available in the site monograph (Claud *et al.* 2025).

This analysis focused only on edged tools (*i.e.*, bearing a sharp edge or dihedron, raw or retouched, that could have been used for cutting, chopping or scraping) in order to discuss their complementarity with the associated flint implements (also investigated). It relied on a recent experimental reference collection of flakes, denticulates and cleavers made from quartz-quartzite (Claud *et al.* 2019) complemented by an original experimental reference collection produced for the occasion, concerning broken, splitted or worked pebbles of quartz-quartzite and dolerite. The reading grid followed the one proposed by previous studies on use-related edge damage (Clemente Conte & Gibaja Bao 2009; Gibaja Bao *et al.* 2009) or surface damage (Adams *et al.* 2009; Dubreuil & Savage 2014; Hamon & Plisson 2008). A first selection, with the naked eye, ruled out the pieces too altered for further analysis. A second observation, with a stereomicroscope (NexiusZoom NZ.1902-P, up to 30x zoom range), led to the identification of tools with potentially use-related traces, which were later analysed under the metallographic microscope (Nikon Eclipse LV150N, 100x to 500x magnification range, coupled with a DS-Fi2 camera). For the pieces too large to fit under the microscope, elastomer imprints were used (Provil Novo Light©). The heterogeneous aspect of dolerite and granite surfaces (due to crystals' mineralogy, size or orientation) limited the identification of use-related traces on these materials.

### 3.4. Investigating the spatial dimension through GIS analysis of spatial distribution

The site of Landry yielded a single and sub-horizontal level of controlled homogeneity that was rapidly covered by silt deposits (see above). It is thus sufficiently well preserved for an analysis of its planimetric spatial organisation. Following a previous work that mainly relied on post-excavation data (Brenet *et al.* 2017), we propose here a re-examination of non-flint lithic artefact distribution building on the results provided by the analyses presented above. The objective is to investigate, through the patterns with which artefacts were discarded, the spatial (and temporal) extent of the various aspects of non-flint lithic resources management at the site. Only the north-westernmost sector, which bears evidences of post-depositional perturbation (solifluction; Bertran 2025) will not be considered, even though some structures seems nonetheless preserved (*e.g.*, a knapping scatter; Brenet *et al.* 2017).

We used a GIS software (ArcGIS 10.8) to plot the artefacts and related data on a map of the site showing the larger pieces (drawn from excavation pictures). We mainly focused on the distribution of petrographic groups, technological categories and tool categories in order to discuss the spatial extent of activities related to the production or the use of the various raw materials. In a more prospective manner, we also looked at the spatial distribution of heating alterations, especially concerning otherwise unmodified pebbles or fragments. For this purpose, we documented the presence of several features: full or partial reddening, lustre visible on fracture surfaces, surface cracks and cupules (*e.g.*, Deal 2012). However, the strict association of these features with heating processes being debated (Domanski & Webb 1992; 2007; Driscoll & Menuge 2011; Pop *et al.* 2021), the analysis only distinguished two categories: the artefacts that bear such features (regarded as "possibly heated") and those that do not. The search for refits being not exhaustive, these data are not involved here, even if they would have helped understand the relationships between different areas of the site.

## 4. Results

### 4.1. Petro-archaeological analysis

Quartz and quartzite account for more than half of the assemblage (Table 3; Figure 6). This group appears relatively homogenous in terms of petrological features compared to the others. Next to this, dolerite account for 18.5% of the assemblage, but constitutes more than one third of its total weight due to the presence of several massive blocks (> 10 kg). Ignimbrite (a variety of hardened tuff) forms the third largest group, followed by leucogranite, schist and leptynite (a variety of gneiss). The assemblage also includes diverse minor groups, in particular meta-ignimbrite and ferruginous sandstone (Table 3).

Most of the artefacts correspond to pebbles or pebble fragments, with the only exceptions (less than 6%) being schist slabs and blocks of quartz-quartzite, schist and meta-ignimbrite. All of the main materials relate to geological formations encountered upstream and are documented in the terraces of Isle River (Le Pochat 1979: 18), which thus appear as a potential catchment area. The survey and sampling of the Upper Pleistocene terrace (Figure 7) revealed a petrographic diversity that is in accordance with the one observed in the archaeological assemblage (Table 3). Thus, it is likely that this terrace provided most of the non-flint raw materials used by the Palaeolithic occupants of Landry and that these resources were mainly collected without regard to their lithology.

Table 3. Distribution of the number and weight of artefacts by lithology and comparison with the natural sample from the Upper Pleistocene terrace. *ND = no data.

| | Archaeological assemblage | | | | Natural sample | | | |
|---|---|---|---|---|---|---|---|---|
| **Lithology** | **Number** | | **Weight (g)** | | **Number** | | **Weight (g)** | |
| **Quartz-quartzite** | 1189 | 53.5% | 254135 | 28.1% | 178 | 42.0% | 40398 | 48.6% |
| **Intrusive rocks** | | | | | | | | |
| Dolerite | 411 | 18.5% | 328340 | 36.4% | 139 | 32.8% | 26677 | 32.1% |
| Granite | 106 | 4.8% | 72616 | 8.0% | 20 | 4.7% | 3599 | 4.3% |
| Gabbro? | 2 | 0.1% | 217 | 0.02% | 4 | 0.9% | 301 | 0.4% |
| Syenogranite? | 1 | 0.04% | 212 | 0.02% | - | - | - | - |
| Diorite? | - | - | - | - | 1 | 0.2% | 35 | 0.04% |
| Metagranite? | - | - | - | - | 1 | 0.2% | 42 | 0.1% |
| Intrusive undet. | 2 | 0.1% | 169 | 0.02% | 4 | 0.9% | 445 | 0.5% |
| **Volcanic rocks** | | | | | | | | |
| Ignimbrite | 231 | 10.4% | 111750 | 12.4% | 36 | 8.5% | 3027 | 3.6% |
| Meta-ignimbrite | 26 | 1.2% | 33702 | 3.7% | 10 | 2.4% | 1326 | 1.6% |
| Basalt? | 1 | 0.04% | ND* | - | - | - | - | - |
| Volcanic undet. | 4 | 0.2% | 939 | 0.1% | - | - | - | - |
| **Metamorphic rocks** | | | | | | | | |
| Schist | 99 | 4.5% | 26206.5 | 2.9% | 3 | 0.7% | 702 | 0.8% |
| Leptynite | 90 | 4.0% | 47290 | 5.2% | 15 | 3.5% | 4596 | 5.5% |
| Other gneiss | 4 | 0.2% | 1937 | 0.2% | 3 | 0.7% | 300 | 0.4% |
| Eclogite? | 5 | 0.2% | 1065 | 0.1% | - | - | - | - |
| Amphibolite? | - | - | - | - | 1 | 0.2% | 69 | 0.1% |
| Metamorphic undet. | 5 | 0.2% | 1586 | 0.2% | 1 | 0.2% | 80 | 0.1% |
| **Sedimentary rocks** | | | | | | | | |
| Sandstone | 14 | 0.6% | 1583 | 0.2% | - | - | - | - |
| Limestone | 2 | 0.1% | 8672 | 1.0% | - | - | - | - |
| Calcite | - | - | - | - | 2 | 0.5% | 530 | 0.6% |
| Radiolarite? | 2 | 0.1% | 114 | 0.01% | 1 | 0.2% | 150 | 0.2% |
| Sedimentary undet. | - | - | - | - | 4 | 0.9% | 698 | 0.8% |
| **Undetermined** | 30 | 1.3% | 12350 | 1.4% | 1 | 0.2% | 70 | 0.1% |
| **Total "non-flint"** | **2224** | **100.0%** | **902884** | **100.0%** | **424** | **100.0%** | **83045** | **100.0%** |

During the survey, we also encountered a few schist slabs, showing that the presence of these forms on the terrace is natural, maybe related to ice or vegetation rafting (Bennett *et al.* 1996). Their relative abundance and specific use for mobile art at Landry suggest a special interest of the Palaeolithic occupants for this raw material. On the other hand, we did not encounter any large-sized block comparable to the ones found at Landry (10 to 23 kg, mostly dolerite but also quartzite, ignimbrite and granite). Either their presence directed the human settlement, or the occupants gathered them from other locations. In both cases, it shows the importance of these objects for the occupants of Landry.

Furthermore, the comparison between the archaeological assemblage and the natural collection shows a slight preference for non-angular and larger volumes of quartz-quartzite and of dolerite, as well as for fine-grained varieties of the latter. There is no preferential selection pattern regarding the other main raw materials.

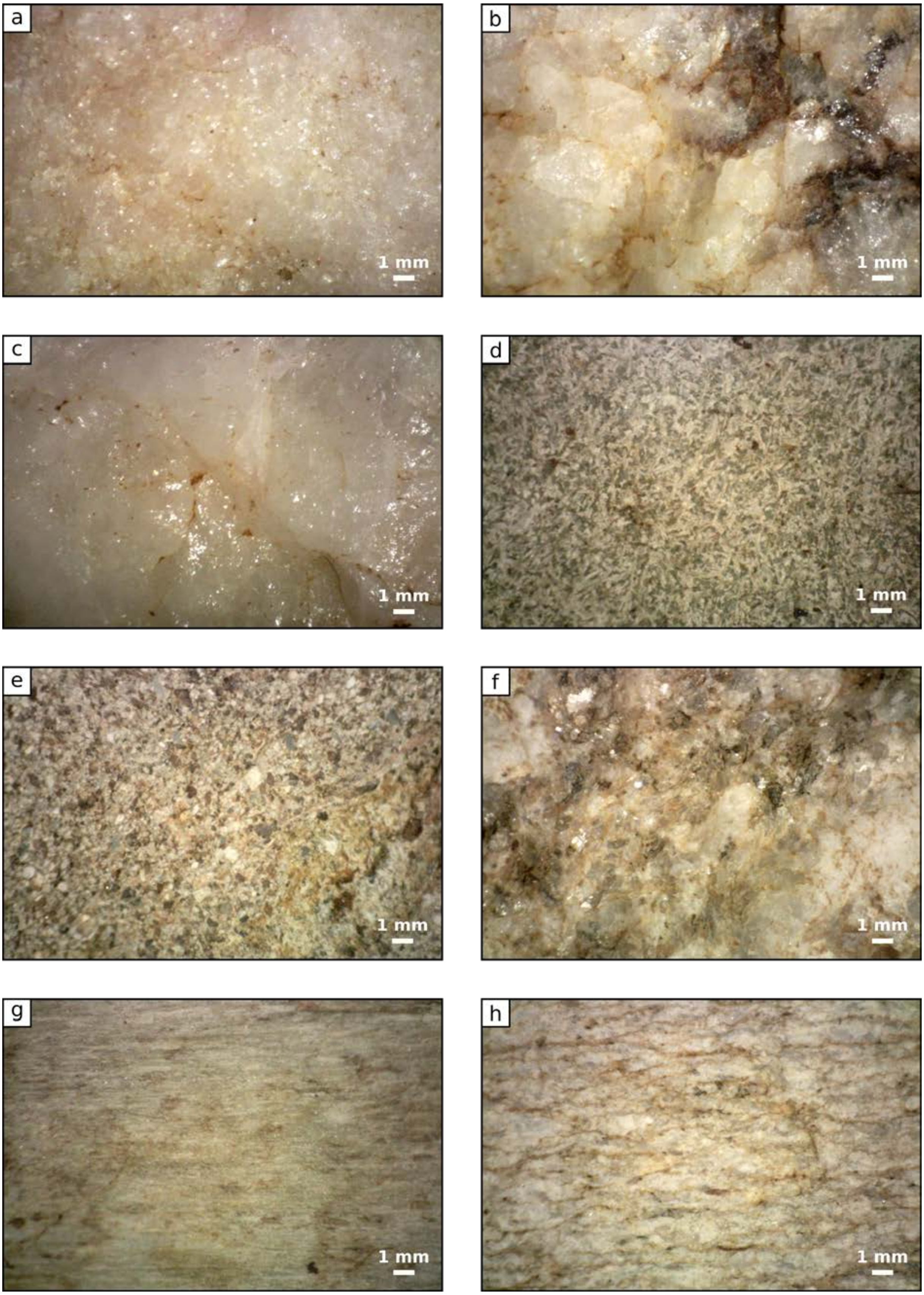


Figure 6. Main raw materials. a: Fine-grained quartzite. b: Very coarse-grained quartzite. c: Xenomorphic quartz. d: Fine-grained dolerite. e: Slightly coarse-grained ignimbrite. f: Coarse-grained porphyroid leucogranite. g: Very fine-grained green schist. h: Fine-grained leptynite (photos Q. Villeneuve).

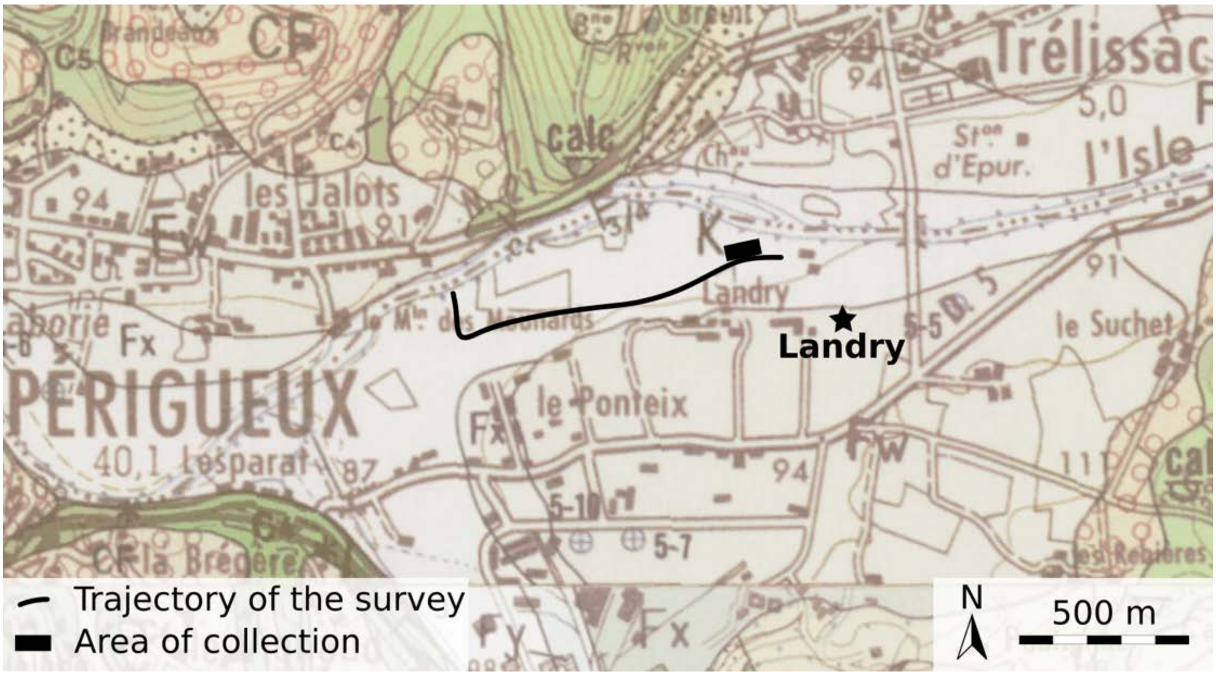


Figure 7. Location of the survey and the area of collection of the comparison sample on the Upper Pleistocene terrace near the site (geological map from the BRGM).

## 4.2. Technological analysis

Debris and other non-diagnostic fragments compose more than half of the assemblage. However, their proportion varies significantly depending on the petrographic group considered (Figure 8, Table 4). The same applies to non-fractured blocks and pebbles, which account for one third of the assemblage. Yet, these two categories do not include only raw objects or knapping waste, as they also provided many tools (see below).

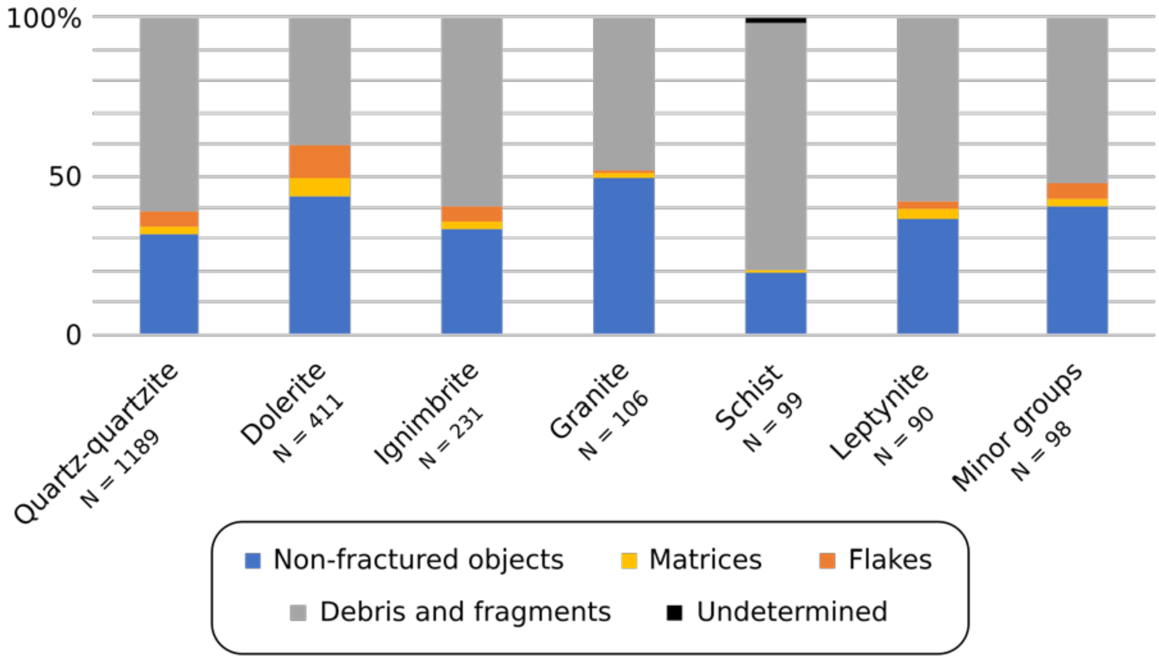


Figure 8. Graph of the distribution of artefacts by technologic category according to raw material.

Table 4 (beginning). Distribution of artefacts by technologic category according to raw material.

| Technologic category | Quartz-quartzite | | Dolerite | | Ignimbrite | | Granite | |
|---|---|---|---|---|---|---|---|---|
| **Non-fractured objects** | 377 | 31.7% | 179 | 43.6% | 77 | 33.3% | 52 | 49.1% |
| **Matrices** | 31 | 2.6% | 25 | 6.1% | 5 | 2.2% | 2 | 1.9% |
| Tested (isolated removals) | 13 | 1.1% | 6 | 1.5% | - | | 1 | 0.9% |
| Shaped | 7 | 0.6% | 5 | 1.2% | 3 | 1.3% | 1 | 0.9% |
| Flaked (cores) | 10 | 0.8% | 14 | 3.4% | 2 | 0.9% | - | |
| Shaped or flaked? | 1 | 0.1% | - | | - | | - | |
| **Flakes** | 58 | 4.9% | 40 | 9.7% | 11 | 4.8% | 1 | 0.9% |
| Complete or sub-complete | 34 | 2.9% | 28 | 6.8% | 9 | 3.9% | 1 | 0.9% |
| Fractured | 23 | 1.9% | 11 | 2.7% | 2 | 0.9% | - | |
| Undetermined | 1 | 0.1% | 1 | 0.2% | - | | - | |
| **Debris and fragments** | 723 | 60.8% | 167 | 40.6% | 138 | 59.7% | 51 | 48.1% |
| **Undetermined (crumbled)** | - | | - | | - | | - | |
| **Total** | **1189** | **100.0%** | **411** | **100.0%** | **231** | **100.0%** | **106** | **100.0%** |
| % Total "non-flint" | | 53.5% | | 18.5% | | 10.4% | | 4.8% |

Table 4 (continued). Distribution of artefacts by technologic category according to raw material.

| Technologic category | Schist | | Leptynite | | Minor groups | | Total "non-flint" | |
|---|---|---|---|---|---|---|---|---|
| **Non-fractured objects** | 19 | 19.2% | 33 | 36.7% | 40 | 40.8% | 777 | 34.9% |
| **Matrices** | 1 | 1.0% | 3? | 3.3% | 2? | 2.0% | 69 | 3.1% |
| Tested (isolated removals) | - | | 1? | 1.1% | - | | 21 | 0.9% |
| Shaped | 1 | 1.0% | 2 | 2.2% | 1 | 1.0% | 20 | 0.9% |
| Flaked (cores) | - | | - | | 1? | 1.0% | 27 | 1.2% |
| Shaped or flaked? | - | | - | | - | | 1 | 0.04% |
| **Flakes** | - | | 2 | 2.2% | 5? | 5.1% | 117 | 5.3% |
| Complete or sub-complete | - | | 2 | 2.2% | 3? | 3.1% | 77 | 3.5% |
| Fractured | - | | - | | 2? | 2.0% | 38 | 1.7% |
| Undetermined | - | | - | | - | | 2 | 0.1% |
| **Debris and fragments** | 77 | 77.8% | 52 | 57.8% | 51 | 52.0% | 1259 | 56.6% |
| **Undetermined (crumbled)** | 2 | 2.0% | - | | - | | 2 | 0.1% |
| **Total** | **99** | **100.0%** | **90** | **100.0%** | **98** | **100.0%** | **2224** | **100.0%** |
| % Total "non-flint" | | 4.5% | | 4.0% | | 4.4% | | 100.0% |

In addition, the assemblage yields modest but nonetheless clear evidence of blank production, especially in the three main groups: quartz-quartzite, dolerite and ignimbrite (Table 4). Angular or flat pebbles of quartz-quartzite and dolerite show evidences of a partial unifacial or bifacial shaping that produced a sharp, roughly dihedral edge on an otherwise unmodified blank (Figure 9; Figure 10, n° 3). Other shaping schemes are punctual, always partial and composed of only one sequence of removals on each face (Figure 10, n° 1 and 2).

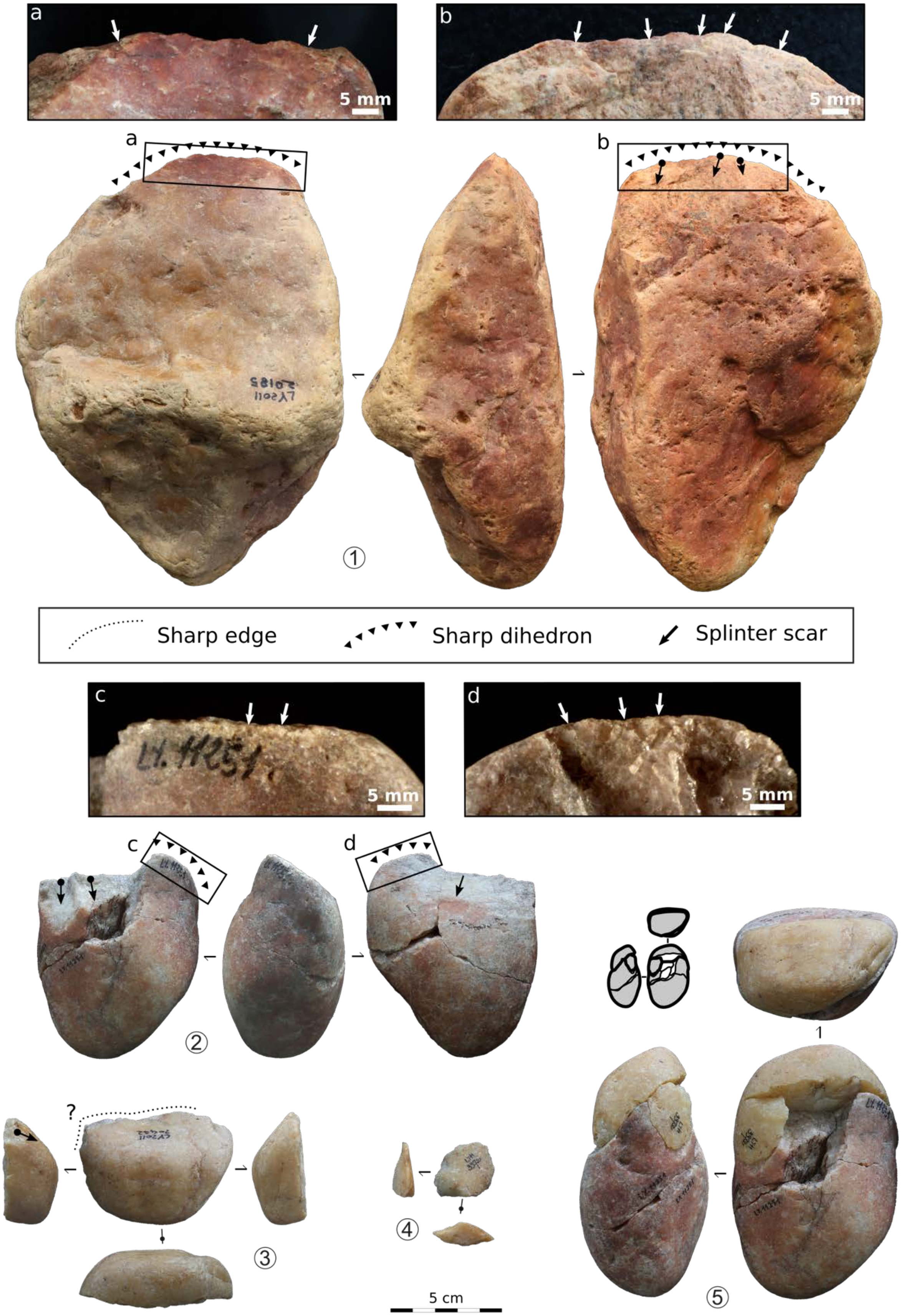


Figure 9. Partial shaping. 1: Worked quartzite pebble with a splintered dihedron (a, b) obtained by partial unifacial shaping. 2: Partially shaped then flaked quartzite pebble with a splintered and blunt dihedron (c, d) incomplete due to small removals posterior to its use (recycling). 3 and 4: Flakes removed from 2. 5: Refit of pieces 2, 3 and 4, showing the reddening of the pebble after its use and reduction (photos Q. Villeneuve).

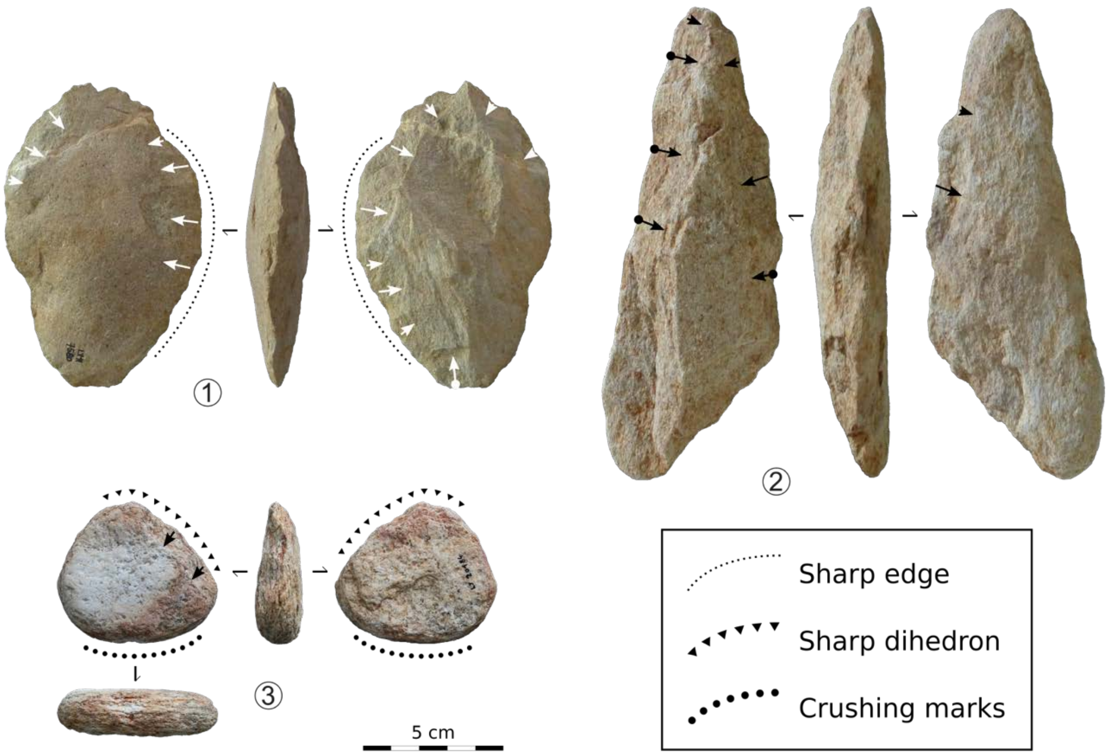


Figure 10. Partial shaping. 1: Ignimbrite flake with a sharp edge obtained by partial bifacial shaping. 2: Ignimbrite pick obtained by partial bifacial shaping. 3: Small flat leptynite pebble with a shaped dihedron opposed to an edge with crushing marks, indicating potential use as intermediary tool (photos Q. Villeneuve).

Flaking concerns mainly quartz-quartzite and dolerite, but also ignimbrite and sandstone in a lesser extent (Table 4; Figure 11; Figure 12). Cores show a low and partial reduction, involving mainly parallelepipedal or angular volumes. Most of these cores (60%) result from specific operative schemes: bipolar-on-anvil (*sensu* Mourre 1996a; 2004), unipolar parallel or centripetal flaking. The others show negatives of removals that are poorly organized. All striking platforms are alluvial surfaces for quartz-quartzite, whereas only 64% are for dolerite. This may be due to the fact that knapped surfaces of quartz-quartzite absorb more the energy of the impact (Tavoso 1986: 34), while it is much less the case for dolerite (Q.V. pers. obs.). This is the only significant distinction between raw materials. Percussion is always direct with a hard hammer. Flakes are not diagnostic of any specific reduction scheme (flakes with a natural butt, back or dorsal face, *etc*.), suggesting that no particular type was sought out even if a variety of schemes were employed. Half of the flakes show knapping accidents, especially Siret fractures. Nonetheless, many (43%) display raw sharp edges (Figure 11; Figure 12). Retouch affects only very few flakes (5%).

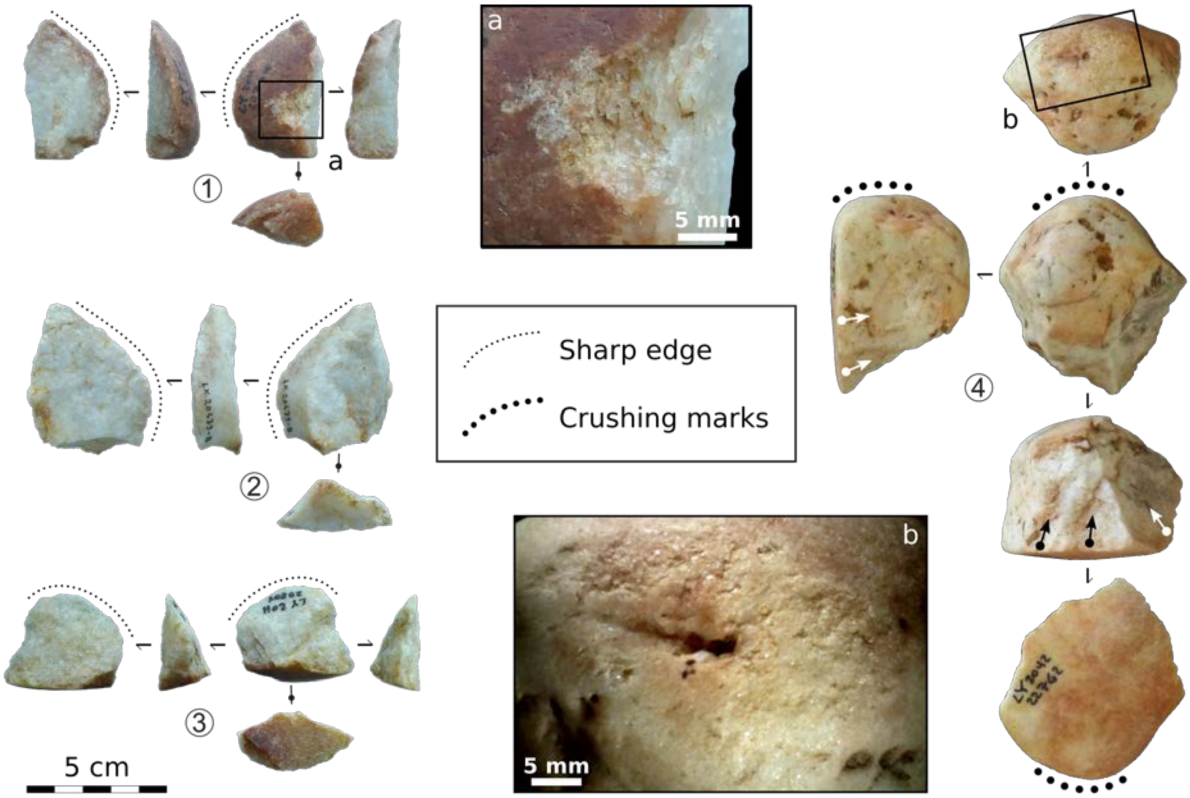


Figure 11. Flaking. 1, 2 and 3: Quartzite flakes with a raw sharp edge opposed to an abrupt one. Crushing marks on the dorsal face of 1 indicates its removal from a percussion tool (recycling). A conjoin between 1 and 2 shows post-knapping reddening. 4: Quartzite core with unifacial centripetal removals indicating its partial flaking as well as crushing marks (b) indicating its use as percussion tool (before or after flaking?) (photos Q. Villeneuve).

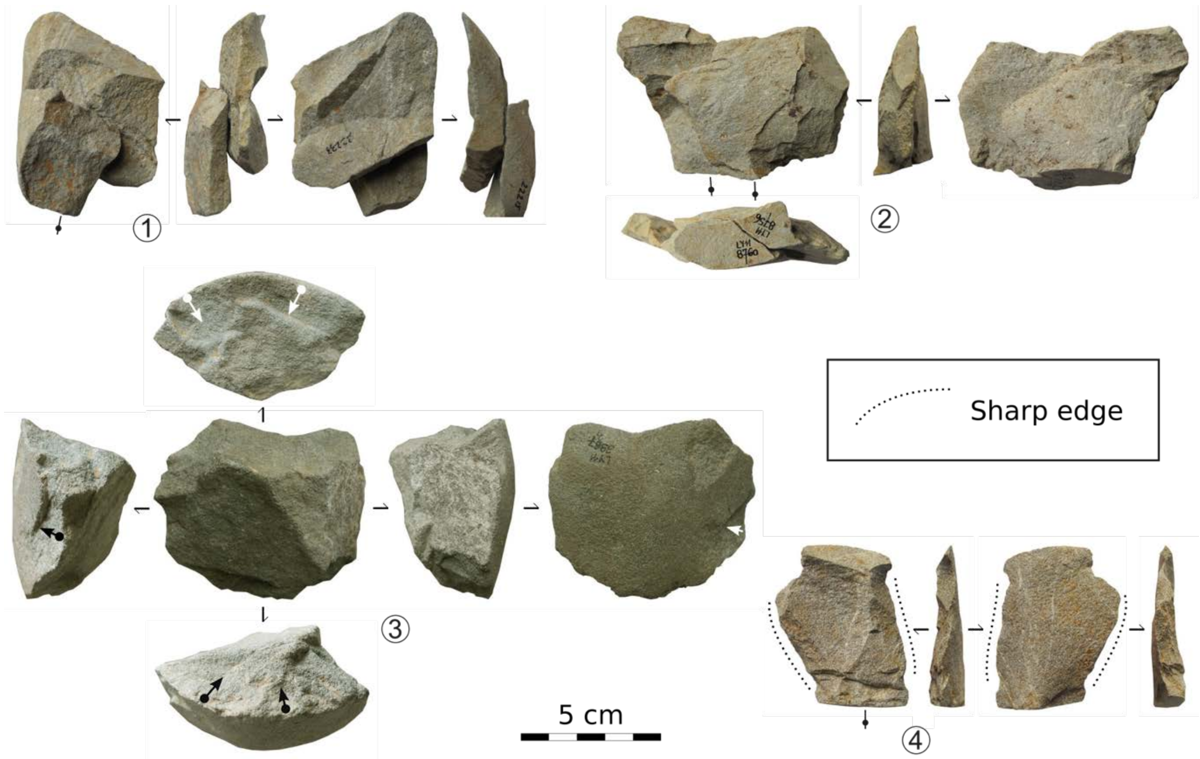


Figure 12. Flaking. 1 and 2: Couples of refitted dolerite flakes. 3: Unifacial centripetal flaking core on dolerite. 4: Ignimbrite flake with two opposite sharp edges, the left one retouched (photos M. Brenet, Q. Villeneuve).

By analysing a sample of debris and fragments from sector 3 (some of them refitted), we identified another reduction method related to splitting (*sensu* Crabtree 1972: 98). Instead of the reduction of an initial volume in order to obtain a shaped residual volume or several flakes, this method consists of dividing an initial volume into two or more smaller fragments of roughly the same size, as observed in other contexts (*e.g.*, Bracco 1993). Here, splitting concerns mostly quartz-quartzite, but also dolerite and leptynite to a lesser extent. The fragments show single, isolated percussion marks initiating the fracture (Figure 13, top), frequently with opposite counter-blow scars (on-anvil percussion). In several cases, the blow targeted a joint, which we suppose would have eased the fracture. Some of these fragments (6 out of 30) display blunt or splintered edges of fractures, demonstrating their subsequent use. Others (16 out of 30) show percussion traces anterior to the splitting (tool recycling?). However, they are difficult to distinguish from fragments resulting from the rupture of percussion tools. The main difference is the presence on the latter of extensive percussion marks or crushing at the initiation of the fracture (Figure 13, bottom). Obviously, this category of artefacts requires further analyses complemented by replication experiments.

A significant number of artefacts (43%), belonging to all technological categories, show alterations supposedly related to heating (*e.g.*, reddening). They are particularly identifiable on refits (Figure 9, n$^{o}$ 5; Figure 11, n$^{o}$ 1 and 2; Figure 13, top). However, confusion is possible with some natural features of the rocks (*e.g.*, red colour). A targeted study of this phenomenon, combining experimentation and luminescence analysis, seem inevitable in order to confirm these observations (Pop *et al.* 2021). Heating could cause rocks to fracture (Domanski & Webb 2007), thus part of the altered debris may have resulted from such process.

### 4.3. Analysis of techno-functional units and related use-wear traces

We identified several tool categories based on the morphology and organization of their techno-functional units and on the type of macroscopic traces their bear (Table 5). This diversified toolkit shows two main modes of tool design.

The first two categories, corresponding to edged tools, involves most of the manufactured blanks produced by shaping (worked pebbles) or flaking (unretouched flakes). Thus, most of them are made from quartz-quartzite, dolerite or ignimbrite. We made the distinction between “heavy” and “light” tools. “Heavy tools with sharp edges” bear splintered or blunt dihedral edges at the end or edge of easy-to-handle volumes (Figure 9, n$^{o}$ 1 and 2). These dihedral edges result from partial shaping (or in few examples from uneven fractures), while the rest of the volume is generally unmodified. Next to these, “light tools with sharp edges” are mainly flakes (along with some small debris) that display a single sharp edge opposed to an abrupt edge or two opposite sharp edges (Figure 10, n$^{o}$ 1; Figure 11, n$^{o}$ 1 to 3; Figure 12, n$^{o}$ 4). In a few cases, a tip extends the sharp edge.

“Splintered intermediary tools” relate to these groups to some extent. They involve small flat blanks of various type (raw or worked pebbles, debris, flakes), mostly of quartz-quartzite. They show a splintered sharp edge or dihedron opposed to a convex end bearing impact marks or crushing (Figure 10, n$^{o}$ 3).

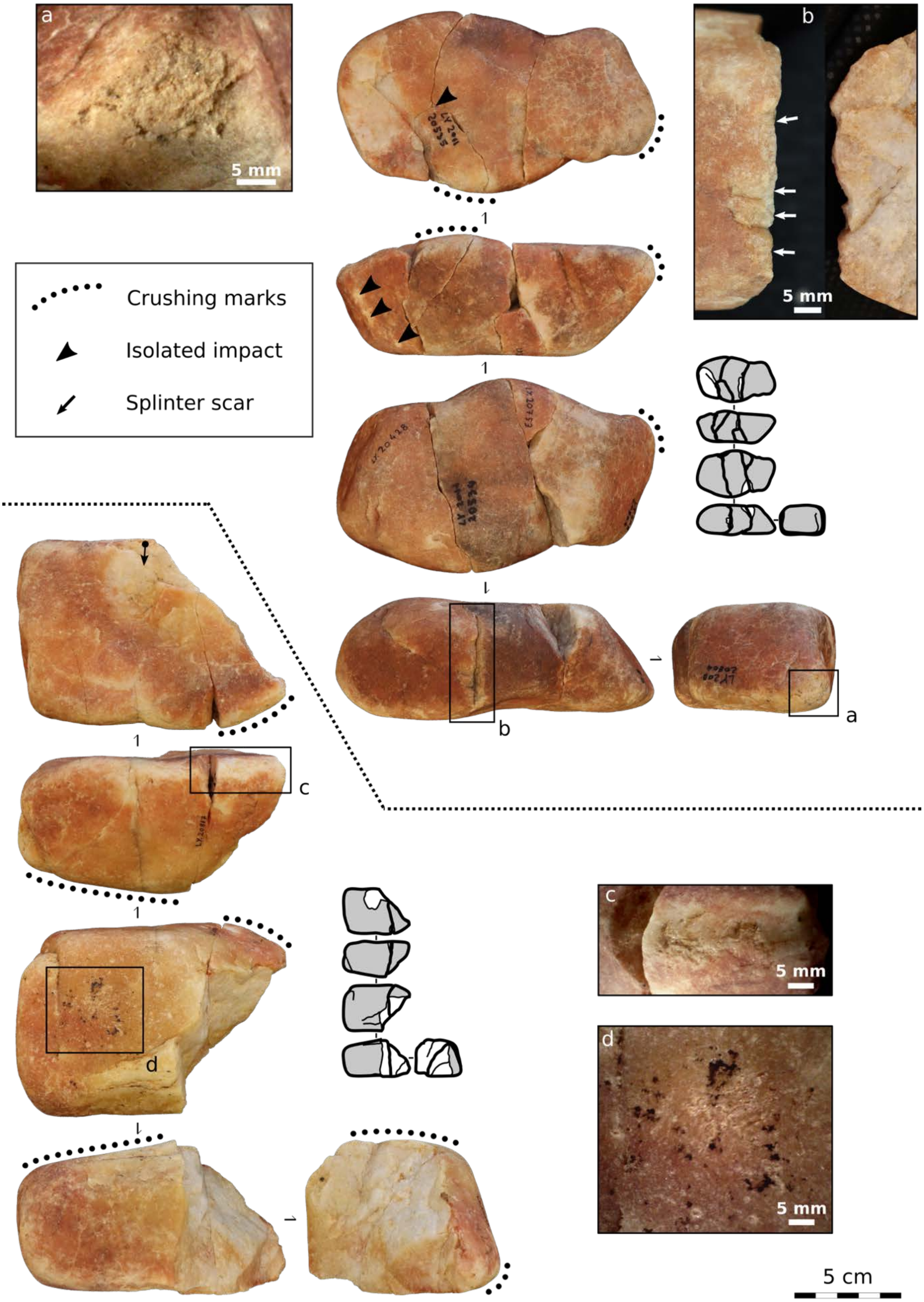


Figure 13. Top: 5-pieces refit of a quartzite pebble with crushing marks (a), recycled by splitting (isolated impact at the centre of a face). The edge of fracture is splintered on some of the fragments (b), evidence of their subsequent use. All show various levels of thermic alteration. Bottom: refit of two quartzite fragments with percussion marks (c, d). The pebble was broken along joints during use (photos Q. Villeneuve).

Table 5 (beginning). Distribution of the number of tools by tool category according to raw material.

| Tool category | | Quartz-quartzite | | Dolerite | | Ignimbrite | | Granite | |
|---|---|---|---|---|---|---|---|---|---|
| Heavy tools with sharp edge | | 5 | 3.8% | 5 | 11.9% | 3 | 15.8% | 1 | 14.3% |
| Light tools with sharp edge | | 42 | 31.6% | 9 | 21.4% | 6 | 31.6% | - | |
| Splintered intermediary tools | | 8 | 6.0% | 2 | 4.8% | - | | - | |
| Tools with impact marks | active | 37 | 27.8% | 4 | 9.5% | 2 | 10.5% | 6 | 85.7% |
| | passive | 18 | 13.5% | 1 | 2.4% | 2 | 10.5% | 1 | 14.3% |
| | undet. | 2 | 1.5% | - | | - | | 1 | 14.3% |
| Tools with levelled surface | active | 29 | 21.8% | 12 | 28.6% | 5 | 26.3% | 1 | 14.3% |
| | passive | 7 | 5.3% | 1 | 2.4% | 2 | 10.5% | - | |
| | undet. | 4 | 3.0% | 1 | 2.4% | - | | - | |
| Passive tools with grooves | | - | | 11 | 26.2% | - | | - | |
| Other tools | | 3 | 2.3% | - | | 1 | 5.3% | - | |
| **Total number of tools** | | **155** | **100.0%** | **46** | **100.0%** | **21** | **100.0%** | **10** | **100.0%** |
| Total number of tool blanks | | 133 | | 42 | | 19 | | 7 | |
| % Total number of tool blanks | | | 60.7% | | 19.2% | | 8.7% | | 3.2% |

Table 5 (continued). Distribution of the number of tools by tool category according to raw material.

| Tool category | | Schist | | Leptynite | | Minor groups | | Total "non-flint" | |
|---|---|---|---|---|---|---|---|---|---|
| Heavy tools with sharp edge | | - | | 1 | 6.7% | - | | 15 | 6.8% |
| Light tools with sharp edge | | 1 | | - | | 1 | | 59 | 26.9% |
| Splintered intermediary tools | | - | | 1 | 6.7% | - | | 11 | 5.0% |
| Tools with impact marks | active | - | | 5 | 33.3% | - | | 54 | 24.7% |
| | passive | - | | 1 | 6.7% | - | | 23 | 10.5% |
| | undet. | - | | 1 | 6.7% | - | | 4 | 1.8% |
| Tools with levelled surface | active | - | | 4 | 26.7% | - | | 51 | 23.3% |
| | passive | - | | 2 | 13.3% | 1 | | 13 | 5.9% |
| | undet. | - | | 1 | 6.7% | - | | 6 | 2.7% |
| Passive tools with grooves | | - | | - | | - | | 11 | 5.0% |
| Other tools | | - | | - | | - | | 4 | 1.8% |
| **Total number of tools** | | **1** | **100.0%** | **16** | **100.0%** | **2** | **100.0%** | **251** | **100.0%** |
| Total number of tool blanks | | 1 | | 15 | | 2 | | 219 | |
| % Total number of tool blanks | | | 0.5% | | 6.8% | | 0.9% | | 100.0% |

The function of these tools was investigated through use-wear analysis (Claud *et al.* 2024, 2025). Most of the light tools with sharp edges bearing informative traces are linked to the scraping of hard mineral material (*e.g.*, pigments) or to the cutting of soft to semi-hard organic material (*e.g.*, meat, hide). Heavy tools with sharp edges appear associated with thrusting percussion (*e.g.*, chopping) while splintered intermediary tools are linked to intermediary percussion (*e.g.*, splitting wedge). Both relate to the processing of hard organic material (bone, antler). Several tools from the three categories bear additional evidences of contact with hard mineral material, indicating the presence of a mineral substrate beneath the organic material being processed. This is in accordance with the large dolerite pebbles or fragments that bear short, shallow and narrow linear marks, spread across a flat surface without apparent organization (Figure 14). These “tools with grooves” were previously identified as passive implements (working surfaces) used in association with active edged tools (Mesa-Saborido 2016: 48).

In opposition to the previous categories, the following ones are multipurpose tools. They rely on a large diversity of non-manufactured blanks (pebbles or fragments of various nature and dimensions), selected opportunistically. These versatile blanks thus frequently combine evidences of two or more (successive or alternate) episodes of use (in the same range of activities or not). “Tools with impact marks” show impact or crushing scars, sometimes associated with partial fractures, on otherwise non-modified surfaces (Figure 13; Figure 15). These traces relate to thrusting hard-hammer percussion (*e.g.*, knapping, crushing) (Cuartero & Bourguignon 2022). We made the distinction between those with traces located on a convex end or edge, while the rest of the volume allows different grip possibilities (regarded as “active” tools), and those with traces located on a flat or slightly convex surface opposed to another roughly flat surface (regarded as “passive” tools). Some of the latter show crushing scars on the rim of the surface, near or on a straight edge, rather than at the centre of it, suggesting the will for a more angular contact.


Figure 14. Large dolerite block showing relatively strait, thin and shallow linear marks on a large face, with no apparent organization (modified after Brenet 2014: fig. 149). It is interpreted as a working surface (Mesa-Saborido 2016).

Next to this, “tools with levelled surface” are volumes bearing a flat (or slightly convex or concave) surface showing levelling and smoothing, sometimes associated with polish or surface cracks. These traces are related to various activities involving diffuse posed percussion (*e.g.*, grinding, smoothing) (Adams *et al.* 2009). The tools showing a levelled surface located on an end, edge or face of an unmodified easy-to-handle pebble were considered “active” (Figure 16). As opposed to this, the ones showing a large levelled surface opposite to a second flat, stable surface on a generally (but not always) voluminous blank were considered “passive” (Figure 17). Further analyses appear essential regarding the use in diffuse posed percussion of these unmodified pebbles (*i.e.*, also bearing alluvial wear).

In addition, the assemblage also includes few other tools that are more difficult to interpret: a weathered bifacial pick (Figure 10, n$^{o}$ 2), two pieces bearing deep parallel grooves (Figure 18) and a fragment with an abraded straight edge.

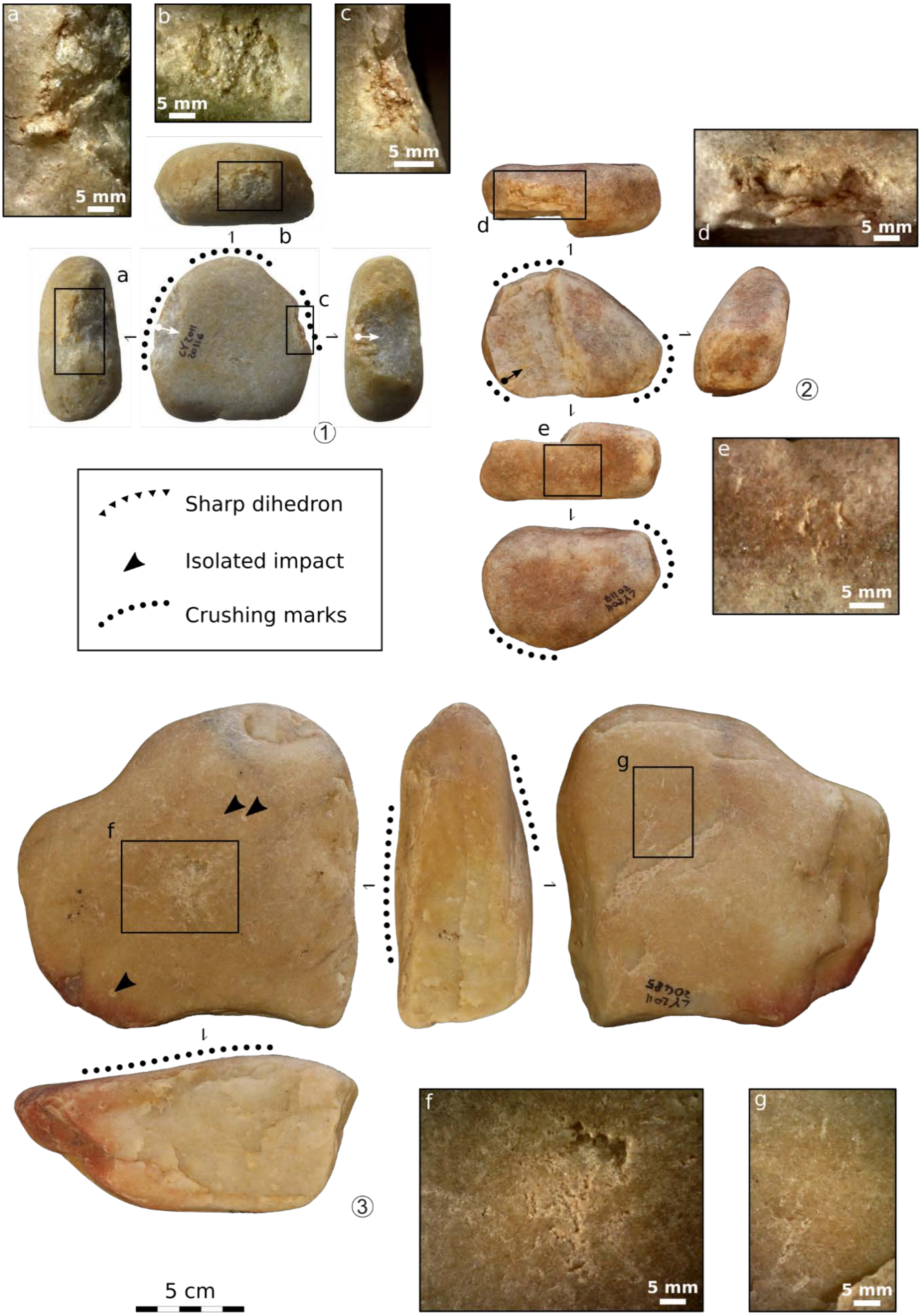


Figure 15. Tools with impact marks. 1 and 2: Quartzite pebbles with impact marks, crushing and accidental flaking (a-e) on convex edges or ends, interpreted as active tools. 3: Quartzite (?) pebble with impact marks and crushing (f, g) on flat surfaces, interpreted as a passive tool. 2 and 3 show linear impact marks (e, g), suggesting a contact with a hard angular material (photos Q. Villeneuve, M. Brenet).

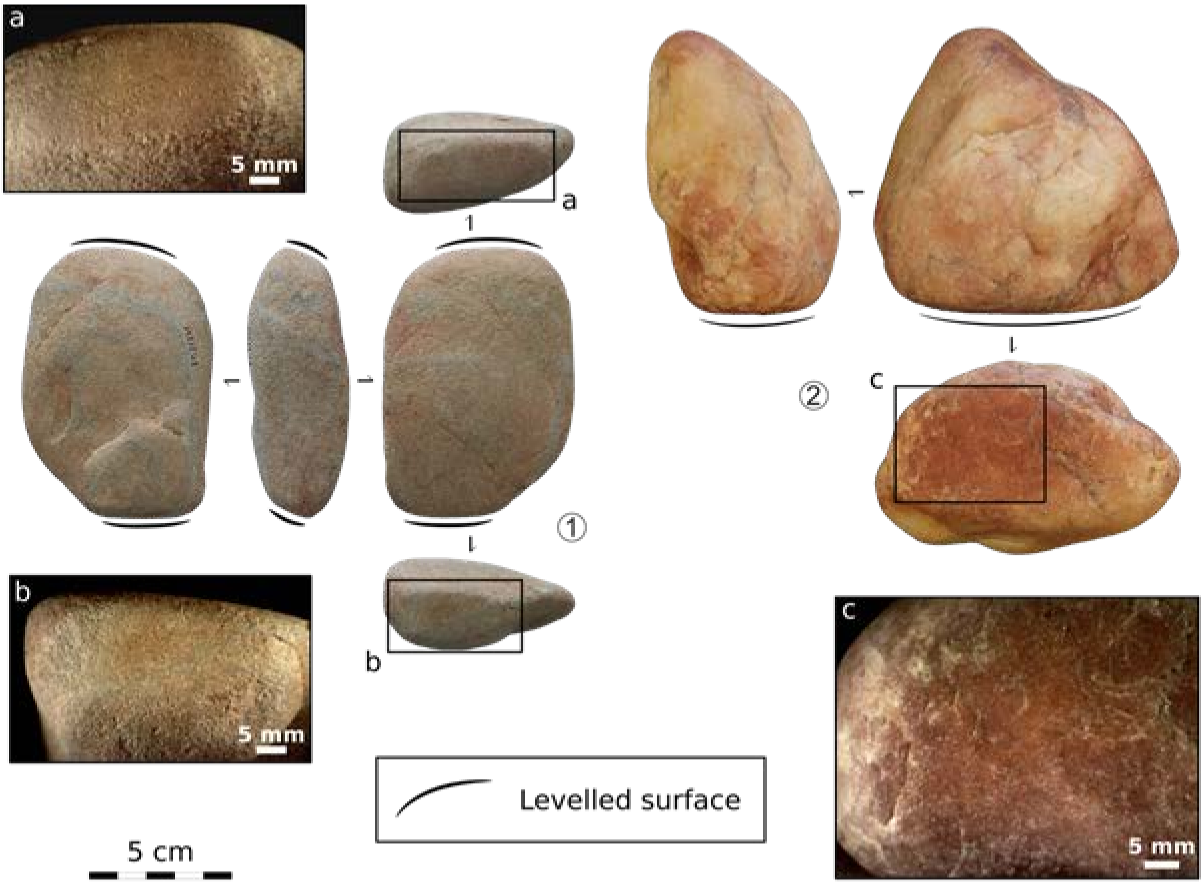


Figure 16. Active tools with levelled surface. 1: Dolerite pebble with a small levelled surface on each end (a, b). 2: Quartzite (?) pebble with a large levelled surface on a face. This surface shows important wear (tribological wear?) on the fringe and surface cracks in the centre (c) as well as reddening (photos Q. Villeneuve).

### 4.4. Analysis of spatial distribution

In order to further the interpretation, we connected the results presented above to the site's spatial organisation. A wide diversity of remains were discovered in the central part of the sectors 2, 3 and 5 (this is less evident for sector 4). These artefacts do not form any concentration, but rather are scattered across large areas, especially in sectors 2 and 3. The presence of pieces of all dimensions suggests that no or only expedient clearing was performed in these areas (Wandsnider 1996). Their archaeological content thus can be regarded as representative of the activities carried out. This includes production waste (*e.g.*, cores) as well as manufactured products (worked pebbles, flakes; Figure 19) and used, broken or recycled tools (Figure 20; Figure 21). This association indicates a mixture of activities, including the production of non-flint stone tools and other activities related to their use. The overlapping of these activities could be related to a differential use of these areas through time (*e.g.*, through successive episodes of occupation). However, it is here associated with short production sequences and simple reduction methods, which suggests a production "on the spot", when the need arise. The reuse and recycling of non-manufactured tools suggests that their management followed a similar process, with the opportunistic selection, among the volumes already present on site, of the ones suitable to the ongoing activities.

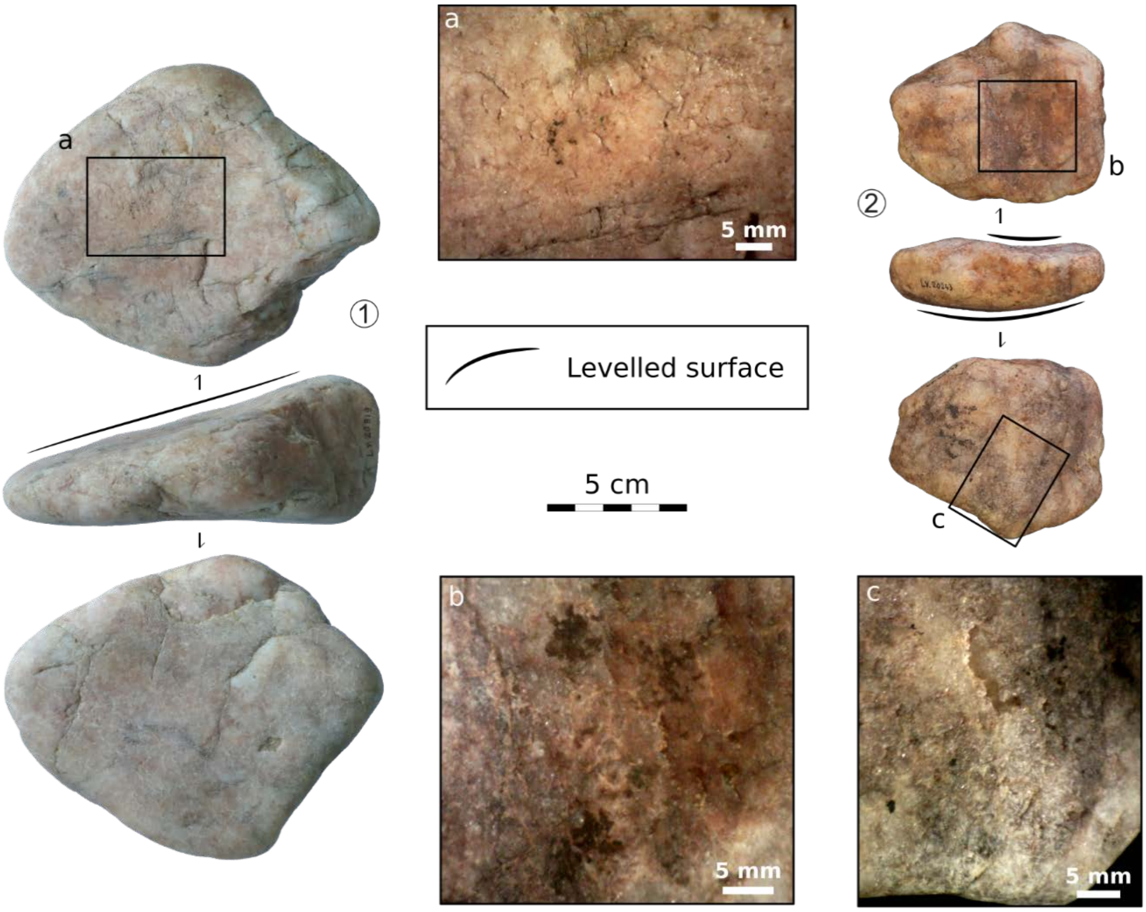


Figure 17. Passive tools with levelled surface. 1: Quartz or quartzite pebble with a large levelled surface on a face. It shows surface cracks (a). 2: Small quartz or quartzite pebble with levelled surfaces on opposite faces. One is slightly concave and of small extent, while the other is large and slightly convex. Both show surface cracks (b, c) (photos Q. Villeneuve).

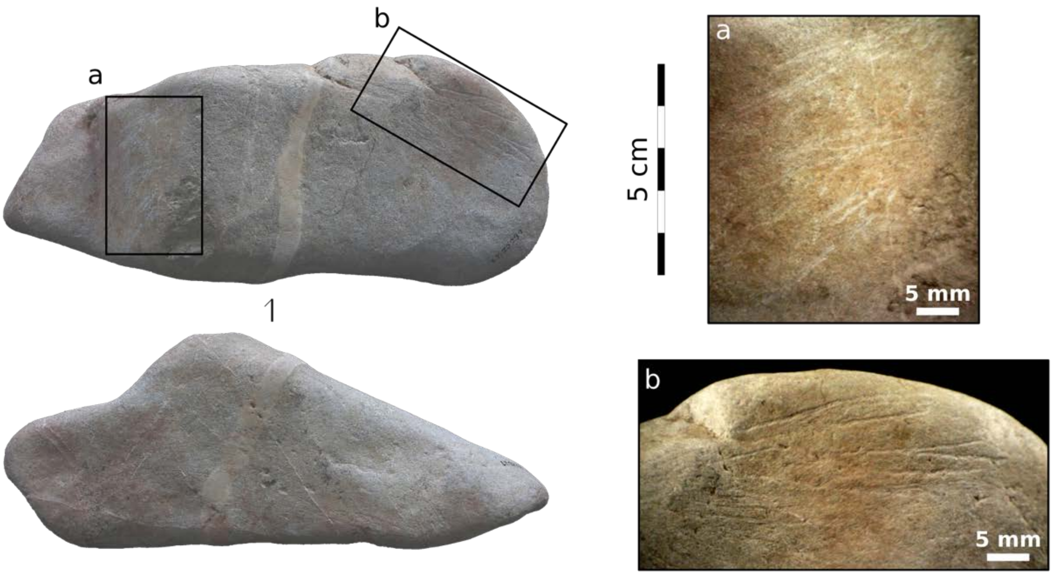


Figure 18. Small dolerite pebble showing two series of linear traces. The centre of a small face displays traces of small extent, subparallel or slightly oblique to each other (a). The fringe of another face shows a bundle of longer traces (b) (photos Q. Villeneuve).

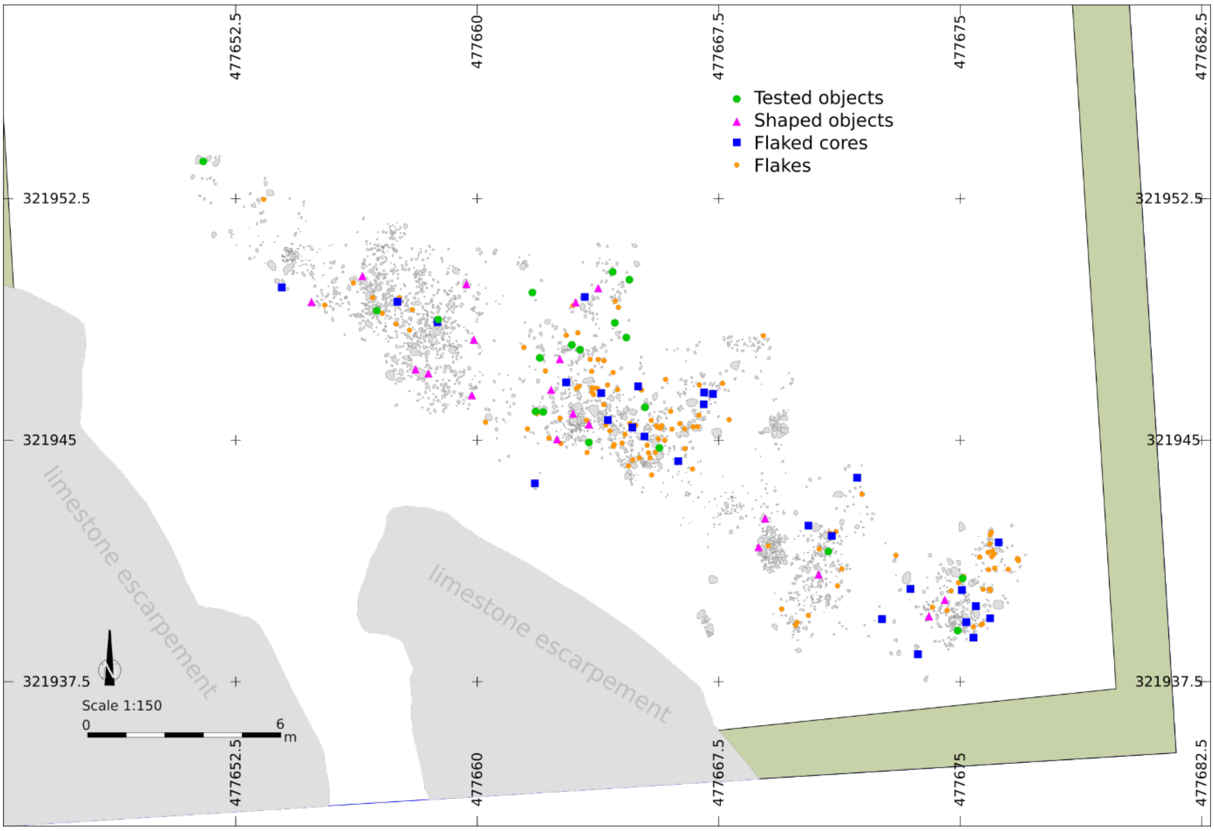


Figure 19. Spatial distribution of manufacture products and waste (illustration V. Pasquet & Q. Villeneuve).

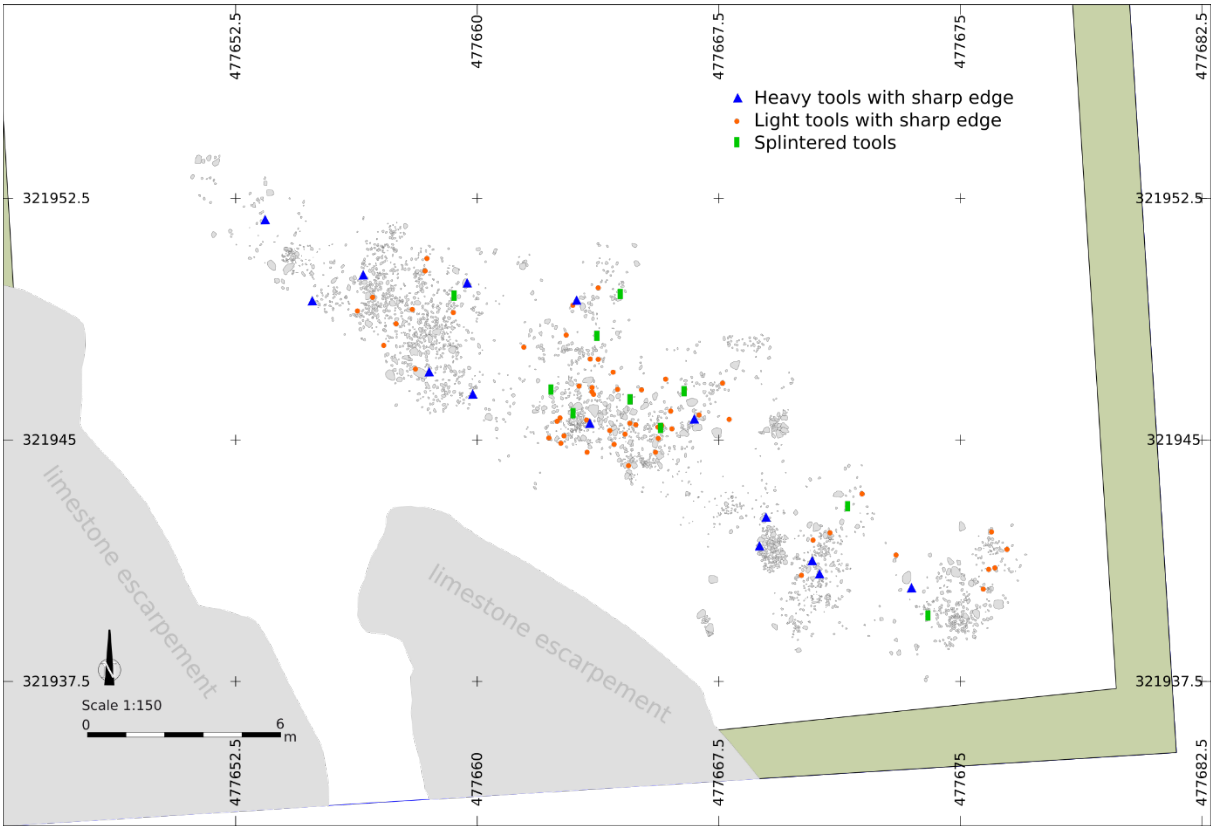


Figure 20. Spatial distribution of manufactured tools (illustration V. Pasquet & Q. Villeneuve).

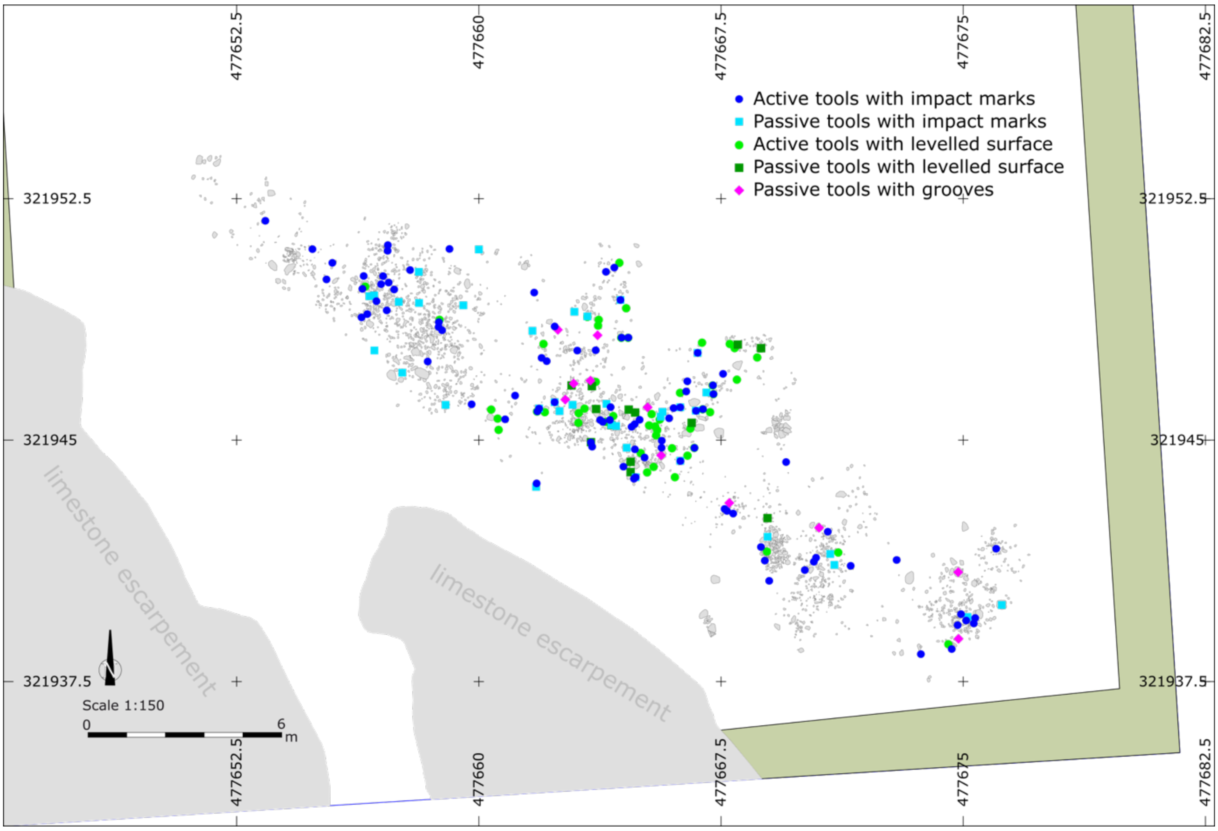

Figure 21. Spatial distribution of non-manufactured tools. Tools with levelled surfaces are over-represented in the central sector due to the sampling strategy (see Table 1) (illustration V. Pasquet & Q. Villeneuve).

Small agglomerates of pebbles (less than 1 $m^2$) were located at the periphery of these central areas (Figure 22). Some included a few tools (manufactured or not) and thus could have been dumps linked to the occasional maintenance of the activity areas. However, these agglomerates were mainly made of unmodified and unheated pebbles. Thus, they may also have acted as stockpiles of raw materials or tool blanks, in accordance with the opportunistic nature of tool production and selection at the site. Other small concentrations including possibly heated pebbles and fragments were located near or inside the large central areas. They could have been hearth structures, around which most activities are often organised in the ethnographic record (Wandsnider 1996). A dedicated study regarding thermic alteration is necessary to confirm this hypothesis since no ash layer was preserved in the silt deposits.

Large blocks (about 10 kg or more) were present in sectors 2, 3 and 5, especially at or near the margins of the large central areas. These implements may have been involved in the spatial structuration of the site, especially by structuring the activities (some of them were used as working surfaces; Mesa-Saborido 2016). There were no archaeological remains underneath these blocks (Brenet in Brenet 2014: 220), indicating their presence prior to any other archaeologically perceptible activities.

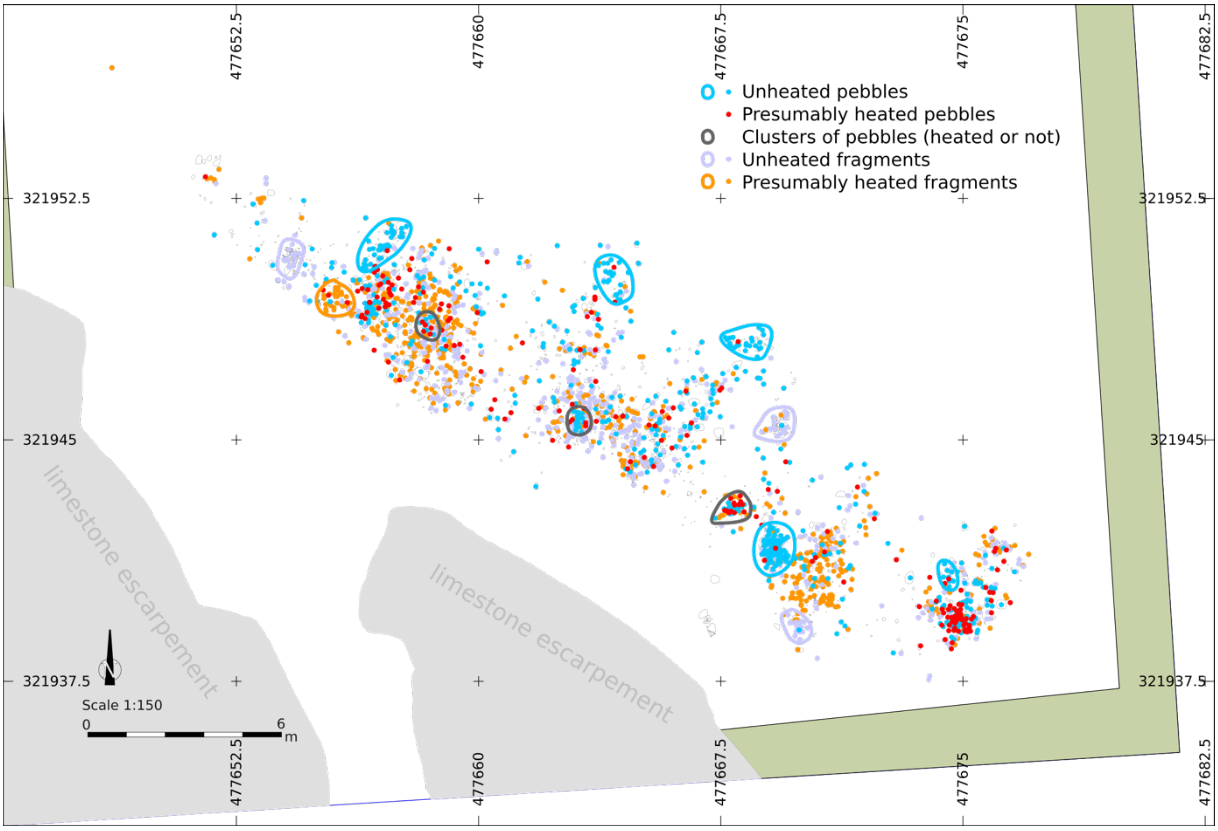


Figure 22. Spatial distribution of possibly heated and non-heated fragments and pebbles (illustration V. Pasquet & Q. Villeneuve).

### 4.5. Inferences

The integration of the results obtained through these different lines of analysis enables a global view of the *chaînes opératoires* associated with non-flint lithic artefacts (Figure 23). The occupants of Landry collected raw pebbles, blocks or fragments of various dimensions and petrographic nature in the immediate vicinity of the site and possibly gathered them near their activity areas, where a differential selection for production or use occurred. Most of the edged tools result from two distinct methods of blank production implemented on rocks more suitable to knapping: quartz-quartzite, dolerite and ignimbrite. Partial shaping provided heavy edged tools, while various short flaking sequences produced light edged tools. These tools were involved in various activities mostly related to the processing of animal resources and mainly through percussive gestures (Claud *et al.* 2025). Other objects were selected for their inherent characteristics and used without further modification: tough rocks for percussion, large flat or parallelepipedal volumes as passive implements, etc. Thus, these were often multi-purpose tools. Production and selection of tools appears expedient and opportunistic, with common recycling or re-use processes. Knapping waste and used tools were probably abandoned on the spot, with no or poor maintenance of the activity areas.

Further analyses could refine or complete these data. Technological and spatial analysis would greatly benefit from systematic refitting. Some particular production schemes (splitting) or techniques (taking advantage of joints) identified here needs confirmation through specific studies and experiments. Use-wear analyses have already shed light on the function of edged or splintered tools (Claud *et al.* 2025). However, other tool categories, especially “tools with levelled surfaces”, also need specific investigation. In addition, further work would be of use in order to consider heating processes and integrate it in the reconstitution of non-flint lithic resources management at the site.

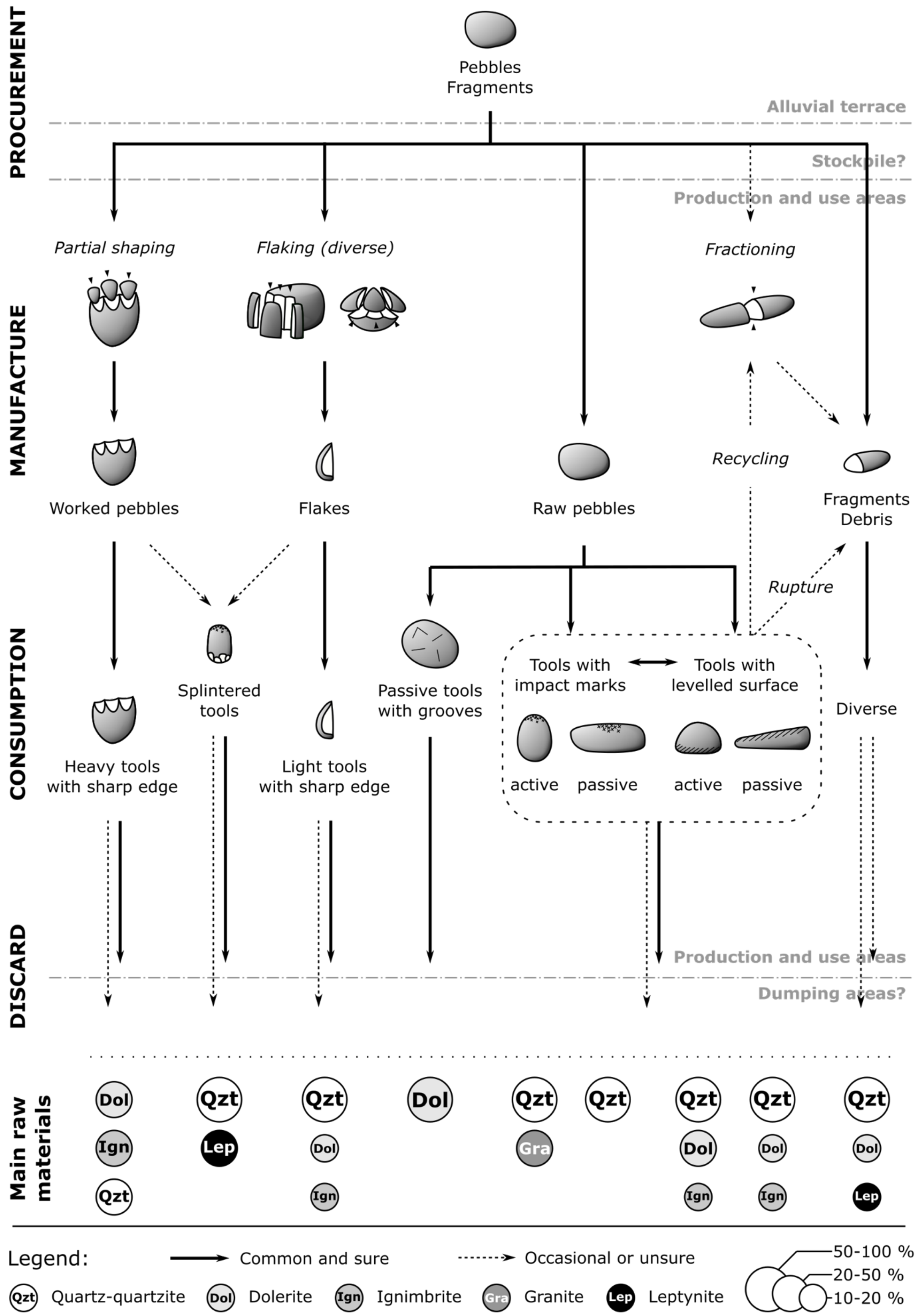


Figure 23. Summary scheme of the *chaînes opératoires* (CAD Q. Villeneuve).

This overview allows nonetheless a direct comparison with the management of flint-like resources at Landry. The alluvial terrace providing the non-flint resources also constitutes the alleged procurement area of the main flint varieties. However, specific tool categories (laurel leaf points, shouldered points, endscrapers) show long-range circulation, with the introduction of finished tools made from distant flint varieties (Delvigne 2025). The manufacture of some of these tools involved thermic treatment (Bachellerie 2022: 225-227). The same categories also result from specific and standardized production methods implemented on the site, especially on dedicated areas (knapping scatters; Brenet *et al.* 2017). In this case, some finished tools are missing, presumably carried out of the site. Next to this, more diversified and less invested flaking methods provided miscellaneous blanks used for various purposes, as we observed for quartz-quartzite, dolerite and ignimbrite. This production also occurred as the need arose, followed by a abandon on the spot (Brenet in Brenet *et al.* 2018: 85-99).

Thus, the two components distinguished here through the duality "flint" *versus* "non-flint" resources appear complementary. While various non-flint resources provided unmanufactured or expedient tools involved in various activities carried out at Landry, including flint management, the latter provided a specific and mobile toolkit following the occupants in their displacements. However, the production of flake blanks through a variety of simple reduction methods on flint as well as on quartz-quartzite, dolerite and ignimbrite raises questions. The ranges of activities related to flint and non-flint tools are nonetheless poorly overlapping (*e.g.*, mineral percussion, use as intermediary pieces; mostly involving expedient or recycled flint tools) (Claud *et al.* 2024; 2025). This suggests a general dissociation in the role played by these two groups of resources in the economy.

## 5. Discussion and perspectives

This case study is a good example of the application of the approach presented above, showing its potential as well as its limitations. The choice to rely mostly on observations at low magnification makes this approach less precise than pinpoint studies involving multi-scalar analyses. It provides nonetheless a comprehensive overview that also points out more specific issues and prepares additional analyses. As an example, the interpretation of some of the artefacts from Landry (in particular "levelled surfaces") would clearly benefit from use-wear analysis. The functional study of all tool categories (not only edged tools) would have been of great interest for the understanding of the activities carried out at the site, but this requires the production of additional reference material. Even if further work would be of use regarding this assemblage, the analyses performed are more than a simple diagnosis. They provided a global, integrated vision of non-flint resources management at the site, with sufficient detail to allow the comparison and combination with the results obtained on other remains (here, flint). This paves the way to a comprehensive description of the technical system of Landry occupants.

Indeed, the approach presented in this paper is still improvable, and we already see several ways to enrich it. The Logical Analytic System (*e.g.*, Carbonell & Rodríguez 2002) relies on a theoretical basis comparable to ours (the *chaîne opératoire* and its subdivisions). It also provides a neutral terminology and interesting means of representation from which our technological analysis would probably benefit. It will be interesting to try to match the two approaches in the future. The techno-functional analysis could be enhanced by including measurement of techno-functional units and precise localization on the volumes, closer to its original form (Lepot 1993). Its association with use-wear analyses and functional experiments appears inevitable, especially in the investigation of non-manufactured implements and their ergonomics. Besides, several experimental works are under consideration in order to define better criteria for the identification of levelled surfaces, splitting processes or thermic treatment. On another note, given that their reconstitution is currently mainly qualitative (Djindjian 2013), it would be interesting to quantify the different steps and variants of the *chaînes opératoires* identified and to associate it to a visual representation in the form of a graph (Djindjian 2013) or a network of relational data (*e.g.*, Kuijpers 2018). We think that this kind of representation would help the identification of strategic stages or alternatives in the processes studied (Lemonnier 1976; 1983).

The main novelty of the approach presented here is the comprehensive vision it provides over the processes of non-flint lithic resources exploitation. In contexts where data concerning this topic are non-existent, scarce or of poor quality, a global approach is still the best way to narrow the gap with the documentation of flint-like resources management, which often already benefits from integrated approaches. Regarding the Upper Palaeolithic in the Aquitaine Basin, this approach is only an early step towards the understanding of non-flint lithic management. We hope that many others will follow as the main outlines start to appear.

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## Data accessibility statement

The authors confirm that the data supporting the findings of this study are available within the article.

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# Explorer la gestion des ressources lithiques hors silex au Paléolithique récent dans le Bassin aquitain à l'aide d'une approche intégrée : application à un cas d'étude du Solutréen récent (Landry, Dordogne, France)

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**Résumé:**

Contrairement aux régions à substrat cristallin, le Bassin aquitain (Sud-Ouest de la France) est un territoire riche en silex et matériaux afférents. Dans cet espace, la production de l'équipement lithique s'est majoritairement appuyée sur l'exploitation de ces matériaux, en particulier au Paléolithique récent. Toutefois, d'autres types de roches représentent fréquemment une part notable du mobilier archéologique. Dans ce contexte, le choix de s'appuyer en partie sur ces matériaux lithiques « hors silex » ne peut correspondre à une stratégie alternative palliant un manque de silex dans l'environnement. La documentation disponible est cependant encore insuffisante pour discuter du rôle économique de ces ressources.

Landry est un site de plein air à niveau unique ayant livré des productions en silex caractéristiques du Solutréen récent (24-23 ka cal. BP) ainsi que de l'art mobilier. La série archéologique comprend par ailleurs un nombre considérable de vestiges lithiques « hors silex », témoignant pour certains d'une production d'éclats ou d'un emploi comme macro-outils. La documentation de cette composante a été jugée essentielle, à la fois pour la compréhension générale du site et pour l'appréhension du rôle économique de ces ressources au Solutréen récent.

Afin d'explorer la plupart des étapes de l'exploitation des roches autres que le silex (et ainsi proposer une approche complète de cette composante), nous nous sommes appuyés sur plusieurs axes d'analyse complémentaires, classiques dans l'analyse des séries en silex mais adaptés afin de prendre en compte les spécificités de ces ressources. L'analyse pétrographique (macro- et mésoscopique) des vestiges, couplée à une prospection de terrain, a mené à l'identification des matières premières et des aires potentielles d'approvisionnement. L'analyse technologique de la série a permis de documenter les méthodes et les objectifs de la production de supports. L'observation des macrotraces d'usure et l'analyse des unités techno-fonctionnelles a offert une première approche de la diversité des outillages (outils non manufacturés notamment). Les outils tranchants ont fait l'objet d'une analyse tracéologique complémentaire. Enfin, l'analyse de la distribution planimétrique des artefacts lithiques « hors silex » a révélé l’organisation spatiale des processus et activités associés.

À Landry, la série lithique « hors silex » investit un large éventail de matériaux (quartz-quartzite, dolérite, ignimbrite, etc.) provenant des dépôts alluviaux avoisinants. Les outils tranchants résultent de courtes séquences de débitage (éclats bruts) ou d’aménagement (galets aménagés). D’autres supports, non manufacturés (galets, fragments), participent à un outillage polyvalent (percussion, friction, surfaces de travail, etc.). La production ou la sélection des supports semble avoir eu lieu sur place, au fur et à mesure des besoins. En comparant ces résultats avec les données disponibles concernant la composante en silex, l’étude révèle la complémentarité entre un outillage en silex très mobile et spécialisé (constitué en prévision de besoins futurs) et un outillage en matériaux locaux plus expéditif mais très diversifié (répondant à des besoins immédiats). Cette dichotomie dépasse la division entre silex et autres roches.

Malgré certaines limites, l'approche présentée dans cet article offre une vision globale et intégrée des processus liés à l'exploitation des ressources lithiques « hors silex » sur le site, permettant la comparaison et la combinaison avec d'autres données (*e.g.*, les productions en silex) et préparant des analyses complémentaires.

**Mots-clés:** ressources lithiques hors silex; pétrographie; technologie lithique; unités techno-fonctionnelles; distribution spatiale; Solutréen récent; Bassin aquitain