**Latest updates on the study of the Middle Palaeolithic Lithic assemblages of Cardina- Salto do Boi site (Côa Valley, Portugal)**

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**Abstract**

Cardina-Salto do Boi (Guarda, Portugal) is one of the few studied sites with Middle Palaeolithic occupations in the Côa Valley. These span MIS 6 to MIS 3, which constitutes a favourable circumstance for studying dwelling dynamics diachronically. Most of the information regarding Neanderthal occupation of the site refers to the assemblages belonging to a 6 m2 area (H’/I’-17/19), where the excavation reached the bedrock, and the deposits were subject to absolute dating.

In this study, we tried to understand how the lithic assemblages of two other test areas N/O-15/17 and Z/A’-6/8 could relate to the findings of area H’/I’-17/19. The assemblages of all areas were revised and subject to raw material and technological analysis. These are mostly composed of quartz knapping remains, but a shift in the preferred type of quartz between *ca.* 80 ka - 51 ka and 51 ka - 39 ka could be identified. The vertical distribution of raw materials and the technological traits of the assemblages indicate that the most recent phase of Neanderthal-associated Middle Palaeolithic lithic technology occupation of the site is also present in areas N/O-15/17 and Z/A’-6/8.

**Key-words**

Cardina-Salto do Boi, Côa Valley, Lithic Technology, Quartz, Neanderthals.

**Introduction**

The study of lithic technology is one of the main tools available to archaeologists for understanding how hunter-gatherer groups lived and explored territories but also for evaluating how human actions contributed for site formation processes [1]. Lithic resource economy studies enable archaeologists to put tool production strategies in perspective by emphasizing their connection with the environment these groups inhabited.

The concept of lithic resource economy was introduced by Catherine Perlès in 1981 [2] and later applied and developed for the study of Middle Palaeolithic lithic assemblages from southern France by Jean-Michel Geneste, in his doctoral thesis [3] and further publications [4]. This work was part of a wider research being done by French working groups *Préhistoire et Technologie and Ethnologie préhistorique* at the time [5]. Building on the idea of an enchainment of actions (*chaîne opératoire*) proposed for the knapping activity, it entails that by knowing the origin and characteristics of the raw materials used and their availability in the environment, one can curtail the territories explored by past human groups [4]. This approach to reconstruct mobility and provisioning habits needs to refer to the technological characteristics of the assemblages being studied, since their specific demands influenced positively the adopted provisioning strategies.

In this sense, provisioning studies have shown that in many archaeological assemblages of western Europe dating from the Middle Palaeolithic local raw materials predominate over exogenous ones [6]. Thus, where quartz was the main lithic resource available, it was skilfully used, such was the case, among others, of Neanderthal groups at Calvero de la Higuera (Madrid, Spain) [7], Teixoneres Cave (Barcelona, Spain) [8], Jarama (Guadalajara, Spain) [9], Maltravieso (Cáceres, Spain) [10], Cova Eirós (Triacastela, Spain) [11], Ciota Ciara (Piedmont, Italy) [12], Figueira Brava (Setúbal, Portugal) [13] and Cardina-Salto do Boi (Guarda, Portugal) [14] (fig. 1).

Uma imagem com texto, mapa, atlas

Descrição gerada automaticamente

**Figure 1.** Location of the archaeological sites mentioned in the text.

For a long time, the use of quartz as a raw material in lithic industries was considered the unfortunate result of availability constrictions or even absence of better suited lithic resources within the catchment area of archaeological sites [15, 16]. This bias was due to the high rate of fragmentation of quartz during knapping and a related high unpredictability of its breaking patterns [17], which can be attested by the less standardised morphologies of the obtained products in this raw material. . However, increasing evidence suggests that hunter-gatherers understood the qualities of different quartz types, and the wide range of strategies they used to explore it points to an unexpected adaptability in how it could be utilized [18], not necessarily driven by the need or urgency with which it has often been evaluated.

At Cardina-Salto do Boi site the lithic knapping remains were produced mostly in quartz (80-90%). Given the importance of this site for understanding the occupation of the Côa valley, and region, by Neanderthal groups, a deeper analysis of the assemblages could not be postponed.

**Archaeological site**

Cardina-Salto do Boi is an archaeological site located on the left margin of the Côa river, situated at the western limit of the Iberian Meseta, in Guarda, Portugal (fig. 1). The site was discovered in 1995, when surveys were being undertaken to look for archaeological sites that could give context to the palaeolithic rock art found a few years earlier throughout the river course [19]. Since then, it has been subject to archaeological excavations, the last campaign having been in 2019 [14].

The site is composed of two platforms, Cardina I and II, the later having resulted from material displacement from Cardina I by colluvial processes [19, 20].

Throughout the excavation campaigns, many areas were tested and extended to better characterise spatial distribution of the artefacts and structures, but only 6m2 test area H’/I’-17/19 (from now on referred to as area H) was excavated to the bedrock and subject to absolute dating (Optically Simulated Luminescence)[[1]](#footnote-1) [21] (fig. 2).

The stratigraphy of the site is composed of eight geoarchaeological field units (GFU). GFUs 8-5 are of alluvial origin and belong to a phase when the site stood at the edge of the floodplain of the river [21]. Between the deposition of GFUs 5 and 4, the distance of the river to the site increased, prompted by both the narrowing of the riverbed and the tectonic fracturing of a rhyolite dike that crosses the river in a E/W direction [22]. This shift in the river course increased gravity lead processes of sedimentation that underlay the deposition of GFU 4-GFU1 [21]. The GFUs 4 to 7 were excavated by 5-cm-thick artificial units (AU) in order to place the non-piece-plotted artefacts recovered by water sieving (2-mm grids).

**Uma imagem com texto, captura de ecrã, mapa

Descrição gerada automaticamente**

**Figure 2.** Plan and Profile A of Cardina-Salto do Boi site. The position and result of absolute data (in ka) samples have been signalised. This image was adapted from previous publications [14]. Photo © João Paulo Ruas.

Vertical displacement of materials, up to a distance of 20 cm, has been attested in test area H through refitting [21].

Human occupation of the site dates back to 155 ka (GFU 7) and extends to the present, making the 5-m thick stratigraphic sequence of the site one of the most complete in the region. Both Upper Palaeolithic and Middle Palaeolithic lithic remains have been recovered [23]. The most recent deposit containing lithic remains that can be assigned to the Middle Palaeolithic, basing ourselves on the reduction sequence technology observed, has been dated to ca. 39 ka and the earliest date obtained for Upper Palaeolithic technology at the site is 34 ka [14]. A stratigraphical disconformity, interpreted as a deposition hiatus, has been identified between the deposits containing Middle Palaeolithic and Upper Palaeolithic technology [21].

The archaeological remains of Cardina - Salto do Boi have already been subject to a diagnostic technological analysis and their characteristics summarised [14]. In this study, the authors did a cluster analysis of the archaeological assemblages of all the excavated areas, crossing variables such as technological traits of the materials, type of raw material and excavation field units. They obtained three clusters characterised by a high correspondence with their own interpretation of the technology and stratigraphy. Cluster 1 grouped artificial units (AU) 25 to 38 of GFU 5 with a thermally altered type of quartz and the employment of prismatic reduction strategies [14].

Cluster 2 comprised levels under AU 6 of GFU 5 and was also characterised by the predominance of local raw materials and flakes produced by prismatic, discoid centripetal bifacial or multifacial methods [14]. The authors pointed to the fact that some of the upper units placed in this cluster from AU 6 to AU 8 of GFU 5 contained Upper Palaeolithic knapping remains, namely blades produced on prismatic unipolar cores and prepared by a central cresting but also bladelets [14]. In their view, these represent the earliest phase of Upper Palaeolithic occupations at the site, characterised by a higher importance of local raw materials [24].

The upper AU of GFU 5 and almost all the AU of GFU 4 were placed in cluster 3, which was characterised by an increase in frequency of allochthonous raw materials, such as flint and silcretes. Among the knapping remains of these units were retouched bladelets, fragments of micro-gravette and backed points, as well as Noaille burins [14].

The authors concluded that the lithic assemblages recovered at the upper top AU of GFU 5, at GFU 4b and GFU 4 could be assigned to different Gravettian phases and that the data recovered from levels characterised by Middle Palaeolithic technology, in all three areas, confirm the absence of bidirectional blade reduction sequences that characterise the Chatelperronian of France.

Lastly, they demonstrated that the geographical area defined by the distribution of raw material sources of all the assemblages, assigned by their reduction sequence and stone tool types to the Middle Palaeolithic, are smaller than all territories defined for Upper Palaeolithic assemblages recovered at the same site and in the region [24]

The study we currently present follows this research but focuses on the knapping remains attributed to the Middle Palaeolithic. Our goal was to comprehend the technoeconomic characteristics of the assemblages, namely the lithic production of the knapping remains and the resource management it implied. Furthermore, the chrono-cultural positioning of the assemblages of areas N/O-15/17 (from now on referred to as area N) and Z/A’-6/8 (from now on area Z) needed to be specifically addressed and better understood, and we hoped to solve that problem by comparing the assemblages of the three excavated areas regarding their technological characteristics and raw material selection.

**Materials and methods**

In this study, only lithic assemblages were analysed, which amounted to a total of 10985 knapping remains and 49 cores (table 1). These comprised archaeological materials from three 6 m2 excavated areas (H, Z and N), recovered from GFU 5 to 7. Regarding area Z, only the materials from square Z8 (1 m²) and GFU 5 were completely analysed. The materials from GFU 5 AU 1 of the other squares of this area were also included in the analysis. The upper limits of the studied assemblages were GFU 5 AU 10, for area H, and GFU 5 AU 8, for area N.

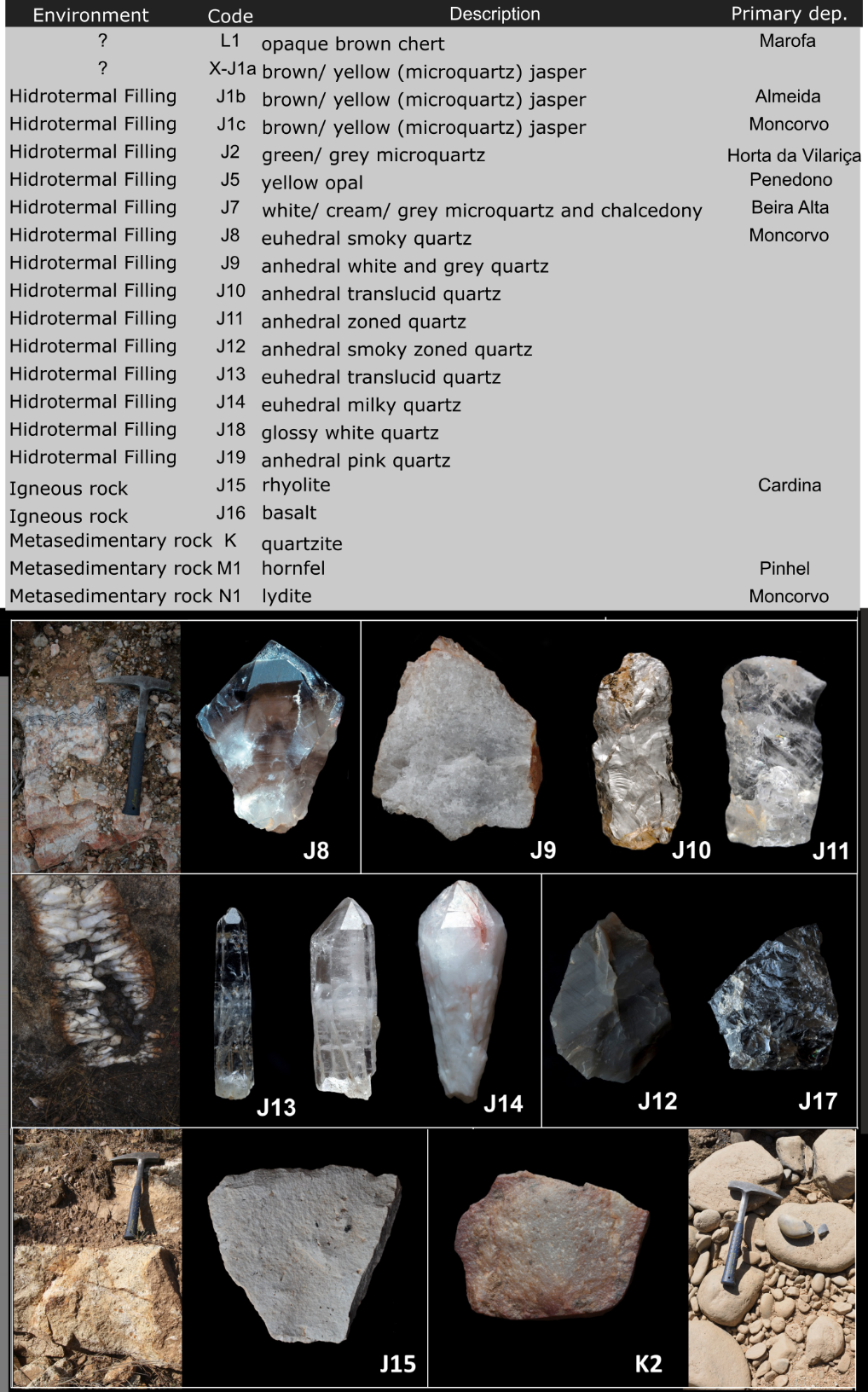
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Technological categories** | **H Area\*** | | **N Area** | | **Z Area** | |
| Cores | 33 | 0.5 % | 12 | 0.5 % | 4 | 0.3 % |
| Flakes | 1493 | 20.4 % | 584 | 25.8 % | 504 | 34.9 % |
| Blades\*\* | 1 | 0 % | 0 | 0 % | 0 | 0% |
| Bladelets | 11 | 0.2 % | 5 | 0.2 % | 12 | 0.8 % |
| Tools | 54 | 0.7 % | 19 | 0.8 % | 5 | 0.3 % |
| Chips | 1143 | 15,6 % | 448 | 19.8 % | 794 | 54.9 % |
| Debris | 4559 | 62.2 % | 1193 | 52.8 % | 123 | 8.5 % |
| **Sum** | 7327 | 100 % | 2261 | 100% | 1446 | 100 % |

\*Two stonehammers were found in this area.

\*\*This classification is merely morphometrical.

**Table 1.** Knapping remains by technological categories for each excavated area.

All the lithic remains were classified by raw material using the categories and code convention stipulated in previous studies [14] (fig. 3). This allowed us to study variations in raw material representativity throughout the stratigraphic sequence and any possible relationships between knapping methods and raw material. For this we used the 5-cm-thick AU as our basic unit for comparison.



**Figure 3.** Typology used for identifying raw materials, adapted from previous publications [14].

The knapped remains were studied with reference to their position in the operative chain through which they were obtained, following the concept of *chaîne opératoire* proposed by André Leroi-Gourhan for archaeology [25] and later improved by other authors [4, 26, 27].

For this study, we began by classifying the knapping products typologically (i.e. cores, flakes, chips, *debris*).

The criteria we used to describe flakes were their completeness regarding the technological axis, the presence or absence of natural surface, the direction of the previous extractions, type of percussion platform and dimensions (length, width, thickness in mm, weight in grams). The flakes under 10 mm were classified as chips. All products which could not be fit into a knapping sequence due to unreadable technological traits were considered *debris*.

Unfortunately, only occasionally did we ascribe blanks to knapping methods, when their characteristics were unmistakable. However, this bears the consequence that with the current data we have, it is impossible to quantify the frequency of knapping methods among blanks reliably, and we believe a future assessment should be made.

Some lithic remains were drawn and described using a diacritic diagram.

The criteria we used to determine knapping methods were the functional relationship between core surfaces and the way they were maintained. For the classification we followed the terminology proposed by François Bordes [28] and Eric Boëda [29, 30] regarding *Levallois* production; Paloma de la Peña [31] for bipolar on anvil technique; we based ourselves on Marco Peresani [32], Xavier Terradas [33], Vincent Mourre [34] and Thomas and Gravina [35] to interpret discoid strategies; our classification of prismatic and polyhedric cores follows João Zilhão’s [36]; and, lastly, to distinguish Kombewa cores we used the guidelines proposed by Marie-Louise Inizan et al. [1], Jacques Tixier and Alain Turq [37].

The statistical analysis was done with *excel*. To study the distribution of the sample in relation to the dimension of the knapping remains, namely flakes, the width and thickness were used. Only complete flakes and tools were plotted by length and width. Cores were weighted.

**A note on raw materials**

In this study, as stated before, we adopted the code convention used in previous works, therefore we followed the characterization that already existed, which is based on the lithological and physical attributes of each lithic resource.

It should be mentioned, however, that the J18 type of quartz or glossy white quartz is known to be either J10 or J11 type of quartz altered by exposure to heat [14]. An experimental test was undertaken, where both anhedral milky quartz (J9) and the anhedral translucent type (J10) were heated and only the translucent variant became similar to the archaeological specimens.

It should also be noted that J9, J10 and J11 type of quartz are all xenomorphic, but present different characteristics related to crystallization dynamics and environments. J11 has bands which appear to be associated with formation environments characterised by some instability. Both J10 and J11 are of finer quality and easier to work with. Nevertheless, there are some fine grained J9 types which break rather smoothly.

J9 type of quartz is the most commonly found in the region.

**Results**

The technological and morphometric characteristics of the knapping remains (ie. tab. 2 to 8) as well as the analysis of the distribution of raw materials by AU (fig. 4) allowed us to identify some patterns within the assemblages.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Area** | **Stratigraphic units** | **Core types** | **Percentage** | **Frequency** |
| **H** | **GFU 6-7** | Centripetal | 50 % | 1 |
| Tested block | 50 % | 1 |
| **GFU5 AUs 38-20** | Bipolar on anvil | 4 % | 1 |
| Centripetal | 9 % | 2 |
| Discoid | 17 % | 4 |
| Levallois | 4 % | 1 |
| Polyhedric | 22 % | 5 |
| Prismatic | 31 % | 7 |
| Tested block | 13 % | 3 |
| **GFU5 AUs 19-10** | Polyhedric | 25 % | 2 |
| Prismatic | 25 % | 2 |
| Tested block | 50 % | 4 |
| **N** | **GFU5 AUs 18-11** | Discoid | 16 % | 1 |
| Polyhedric | 17 % | 1 |
| Prismatic | 50 % | 3 |
| Tested block | 17 % | 1 |
| **GFU5 AUs 10-8** | Bipolar on anvil | 16 % | 1 |
| Discoid | 17 % | 1 |
| Polyhedric | 17 % | 1 |
| Prismatic | 50 % | 3 |
| **Z** | **GFU5 AUs 15-10** | Discoid | 50 % | 1 |
| Tested block | 50 % | 1 |
| **GFU5 AUs**  **9-6** | Prismatic | 100 % | 1 |
| **GFU5 AUs**  **5-1** | Prismatic | 100 % | 1 |

**Table 2.** Quantitative distribution of core types throughout the stratigraphic sequence. These data needed to be integrated into the wider technological analysis because the number of cores is relatively small and does not account for all the knapping remains that were found.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **H area** | | | | | | |
| **Technological traits** | **GFU 6-7** | | **GFU5 AUs 38-20** | | **GFU5 AUs 19-10** | |
| **Cortex** | **%** | **N** | **%** | **N** | **%** | **N** |
| Cortical | 13 % | 13 | 9 % | 75 | 12 % | 68 |
| Partially cortical | 30 % | 29 | 16 % | 130 | 66 % | 372 |
| Without cortex | 57 % | 55 | 75 % | 629 | 22 % | 122 |
| **Previous extractions** |  | | | | | |
| Unipolar | 75 % | 66 | 83 % | 637 | 78 % | 385 |
| Bipolar | 1 % | 1 | 2 % | 13 | 5 % | 28 |
| Convergent | 24 % | 21 | 15 % | 114 | 17 % | 83 |
| **Platform angle** |  | | | | | |
| ≤ 45° | 0 % | 0 | 2 % | 18 | 5 % | 31 |
| 90° | 9 % | 9 | 7 % | 57 | 13 % | 71 |
| 90°- 45° | 67 % | 65 | 47 % | 392 | 40 % | 223 |
| Undetermined | 24 % | 23 | 44 % | 367 | 42 % | 237 |
| **Type of platform** |  | | | | | |
| Cortical | 10 % | 10 | 7.7 % | 64 | 17.8 % | 100 |
| Flat | 63 % | 61 | 43.9 % | 366 | 38.1 % | 214 |
| Facetted | 4 % | 4 | 4.6 % | 38 | 6.2 % | 35 |
| Microfacetted | 0 % | 0 | 0.1 % | 1 | 0.2 % | 1 |
| Scarred linear | 4 % | 4 | 7.0 % | 59 | 7.8 % | 44 |
| Punctiform | 4 % | 4 | 4. 7 % | 39 | 5.3 % | 30 |
| Undetermined | 15 % | 14 | 32.0 % | 267 | 24.6 % | 138 |
| **Completeness** |  | | | | | |
| Complete | 52 % | 50 | 46 % | 387 | 46 % | 259 |
| Proximal fragment | 20 % | 19 | 12 % | 98 | 17 % | 96 |
| Distal fragment | 8 % | 8 | 19 % | 160 | 16 % | 91 |
| Mesial fragment | 5 % | 5 | 11 % | 91 | 7 % | 38 |
| Siret | 15 % | 15 | 12 % | 97 | 14 % | 78 |

**Table 3.** Technological traits of flakes from area H.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **H area** | | | | | | |
| **Technological traits** | **GFU 6-7** | | **GFU5 AUs 38-20** | | **GFU5 AUs 19-10** | |
| **Cortex** | **%** | **N** | **%** | **N** | **%** | **N** |
| Cortical | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Partially cortical | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Without cortex | 0 % | 0 | 100 % | 9 | 100 % | 2 |
| **Previous extractions** |  | | | | | |
| Unipolar | 0 % | 0 | 100 % | 9 | 50 % | 1 |
| Bipolar | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Convergent | 0 % | 0 | 0 % | 0 | 50 % | 1 |
| **Platform angle** |  | | | | | |
| ≤ 45° | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| 90° | 0 % | 0 | 0 % | 0 | 50 % | 1 |
| 90°- 45° | 0 % | 0 | 33 % | 3 | 0 % | 0 |
| Undetermined | 0 % | 0 | 67 % | 6 | 50% | 1 |
| **Type of platform** |  | | | | | |
| Cortical | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Flat | 0 % | 0 | 33 % | 3 | 50 % | 1 |
| Facetted | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Microfacetted | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Scarred linear | 0 % | 0 | 33 % | 3 | 50 % | 1 |
| Punctiform | 0 % | 0 | 11 % | 1 | 0 % | 0 |
| Undetermined | 0 % | 0 | 23 % | 2 | 0 % | 0 |
| **Completeness** |  | | | | | |
| Complete | 0 % | 0 | 67 % | 6 | 0 % | 0 |
| Proximal fragment | 0 % | 0 | 0 % | 0 | 100 % | 2 |
| Distal fragment | 0 % | 0 | 22 % | 2 | 0 % | 0 |
| Mesial fragment | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Siret | 0 % | 0 | 11 % | 1 | 0 % | 0 |

**Table 4.** Technological traits of bladelets from area H.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **N area** | | | | |
| **Technological traits** | **GFU5 AUs 18-11** | | **GFU5 AUs 10-8** | |
| **Cortex** | **%** | **N** | **%** | **N** |
| Cortical | 16 % | 59 | 11 % | 23 |
| Partially cortical | 67 % | 253 | 14 % | 29 |
| Without cortex | 17 % | 64 | 75 % | 155 |
| **Previous extractions** |  | |  | |
| Unipolar | 91 % | 289 | 77 % | 141 |
| Bipolar | 2 % | 6 | 3 % | 5 |
| Convergent | 7 % | 21 | 20 % | 37 |
| **Platform angle** |  | |  | |
| ≤ 45° | 0 % | 0 | 2 % | 3 |
| 90° | 0.5 % | 2 | 7 % | 4 |
| 90°- 45° | 62.8 % | 236 | 47 % | 132 |
| Undetermined | 36.7 % | 138 | 44 % | 68 |
| **Type of platform** |  | |  | |
| Cortical | 14 % | 52 | 12 % | 25 |
| Flat | 46 % | 173 | 54 % | 111 |
| Facetted | 2 % | 6 | 1 % | 2 |
| Microfacetted | 0 % | 0 | 0 % | 0 |
| Scarred linear | 5 % | 20 | 5 % | 11 |
| Punctiform | 2 % | 7 | 2 % | 4 |
| Undetermined | 31 % | 118 | 26 % | 54 |
| **Completeness** |  | |  | |
| Complete | 53 % | 199 | 50 % | 103 |
| Proximal fragment | 7 % | 25 | 12 % | 26 |
| Distal fragment | 18 % | 68 | 12 % | 24 |
| Mesial fragment | 12 % | 45 | 9 % | 18 |
| Siret | 10 % | 39 | 17 % | 36 |

**Table 5.** Technological traits of flakes from area N.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **N area** | | | | |
| **Technological traits** | **GFU5 AUs 18-11** | | **GFU5 AUs 10-8** | |
| **Cortex** | **%** | **N** | **%** | **N** |
| Cortical | 0 % | 0 | 0 % | 0 |
| Partially cortical | 0 % | 0 | 25 % | 1 |
| Without cortex | 100 % | 1 | 75 % | 3 |
| **Previous extractions** |  | |  | |
| Unipolar | 0 % | 0 | 100 % | 4 |
| Bipolar | 100 % | 1 | 0 % | 0 |
| Convergent | 0 % | 0 | 0 % | 0 |
| **Platform angle** |  | |  | |
| ≤ 45° | 0 % | 0 | 0 % | 0 |
| 90° | 0 % | 0 | 25% % | 1 |
| 90°- 45° | 0 % | 0 | 50 % | 2 |
| Undetermined | 100 % | 1 | 25 % | 1 |
| **Type of platform** |  | |  | |
| Cortical | 0 % | 0 | 0 % | 0 |
| Flat | 0 % | 0 | 75 % | 3 |
| Facetted | 0 % | 0 | 0 % | 0 |
| Microfacetted | 0 % | 0 | 0 % | 0 |
| Scarred linear | 0 % | 0 | 0 % | 0 |
| Punctiform | 0 % | 0 | 0 % | 0 |
| Undetermined | 100 % | 1 | 25 % | 1 |
| **Completeness** |  | |  | |
| Complete | 0 % | 0 | 50 % | 2 |
| Proximal fragment | 0 % | 0 | 25 % | 1 |
| Distal fragment | 100 % | 1 | 25 % | 1 |
| Mesial fragment | 0 % | 0 | 0 % | 0 |
| Siret | 0 % | 0 | 0 % | 0 |

**Table 6.** Technological traits of bladelets from area N.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Z area** | | | | | | |
| **Technological traits** | **GFU5 AUs 15-10** | | **GFU5 AUs 9-6** | | **GFU5 AUs 5-1** | |
| **Cortex** | **%** | **N** | **%** | **N** | **%** | **N** |
| Cortical | 14 % | 10 | 10 % | 5 | 11 % | 41 |
| Partially cortical | 9 % | 6 | 10 % | 5 | 13 % | 52 |
| Without cortex | 77 % | 53 | 80 % | 38 | 76 % | 294 |
| **Previous extractions** |  | | | | | |
| Unipolar | 92 % | 54 | 95 % | 41 | 89.5 % | 315 |
| Bipolar | 0 % | 0 | 0 % | 0 | 0.6 % | 2 |
| Convergent | 8 % | 5 | 5 % | 2 | 9.9 % | 35 |
| **Platform angle** |  | | | | | |
| ≤ 45° | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| 90° | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| 90°- 45° | 72 % | 50 | 77 % | 37 | 66 % | 256 |
| Undetermined | 28 % | 19 | 23 % | 11 | 34 % | 131 |
| **Type of platform** |  | | | | | |
| Cortical | 12 % | 8 | 10 % | 5 | 12.1 % | 47 |
| Flat | 60 % | 41 | 69 % | 33 | 51.7 % | 200 |
| Facetted | 1 % | 1 | 0 % | 0 | 0.8 % | 3 |
| Microfacetted | 0 % | 0 | 0 % | 0 | 0.5 % | 2 |
| Scarred linear | 7 % | 5 | 0 % | 0 | 6.2 % | 24 |
| Punctiform | 0 % | 0 | 0 % | 0 | 0.3 % | 1 |
| Undetermined | 20 % | 14 | 21 % | 10 | 28.4 % | 110 |
| **Completeness** |  | | | | | |
| Complete | 51 % | 35 | 65 % | 31 | 45 % | 176 |
| Proximal fragment | 8 % | 6 | 8 % | 4 | 11 % | 41 |
| Distal fragment | 13 % | 9 | 4 % | 2 | 12 % | 46 |
| Mesial fragment | 6 % | 4 | 17 % | 8 | 13 % | 50 |
| Siret | 22 % | 15 | 6 % | 3 | 19 % | 74 |

**Table 7.** Technological traits of flakes from area Z.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Z area** | | | | | | |
| **Technological traits** | **GFU5 AUs 15-10** | | **GFU5 AUs 9-6** | | **GFU5 AUs 5-1** | |
| **Cortex** | **%** | **N** | **%** | **N** | **%** | **N** |
| Cortical | 25 % | 1 | 0 % | 0 | 12.5 % | 1 |
| Partially cortical | 0 % | 0 | 0 % | 0 | 37.5 % | 3 |
| Without cortex | 75 % | 3 | 0 % | 0 | 50.0 % | 4 |
| **Previous extractions** |  | | | | | |
| Unipolar | 100 % | 3 | 0 % | 0 | 100 % | 7 |
| Bipolar | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Convergent | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| **Platform angle** |  | | | | | |
| ≤ 45° | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| 90° | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| 90°- 45° | 75 % | 3 | 0 % | 0 | 62.5 % | 5 |
| Undetermined | 25 % | 1 | 0 % | 0 | 37.5 % | 3 |
| **Type of platform** |  | | | | | |
| Cortical | 0 % | 0 | 0 % | 0 | 12.5 % | 1 |
| Flat | 75 % | 3 | 0 % | 0 | 50.0 % | 4 |
| Facetted | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Microfacetted | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Scarred linear | 0 % | 0 | 0 % | 0 | 25.0 % | 2 |
| Punctiform | 0 % | 0 | 0 % | 0 | 0 % | 0 |
| Undetermined | 25 % | 1 | 0 % | 0 | 12.5 % | 1 |
| **Completeness** |  | | | | | |
| Complete | 50 % | 2 | 0 % | 0 | 37.5 % | 3 |
| Proximal fragment | 0 % | 0 | 0 % | 0 | 37.5 % | 3 |
| Distal fragment | 25 % | 1 | 0 % | 0 | 0 % | 0 |
| Mesial fragment | 0 % | 0 | 0 % | 0 | 12.5 % | 1 |
| Siret | 25 % | 1 | 0 % | 0 | 12.5 % | 1 |

**Table 8.** Technological traits of bladelets from area Z.

Uma imagem com captura de ecrã, texto, Saturação de cores, Retângulo

Descrição gerada automaticamente

**Figure 4.** Comparison of the vertical distribution of raw materials by artificial unit and excavated area. The black boxes correspond to the grouping we did based on the patterns we found © Luís Luís, 2023.

Almost all knapping remains of GFU 6/7 of trench H, dated between 155 ka (GFU 7) and *ca.* 80 ka (base of GFU 5), were produced in quartz, particularly the anhedral zoned type of quartz or J11 (n = 80/110). Fewer were obtained from J9 type of quartz (anhedral white/ grey) (n = 20/110). The anhedral translucid type of quartz (J10) and the glossy white type (J18) were not used as well as rock crystal (J13, J14). On the other hand, there are some artefacts in rhyolite (J15) (n =5/110) and quartzite (K2) (n =3/110).

Regarding the technological characteristics of the materials, these attest to the employment of discoid and *Levallois* reduction strategies and among them are the biggest blanks and tools of the whole collection (the biggest tool being 101.52 x 68.61 x 26.69 mm).

Like in these assemblages, among the artefacts from AUs 38-20 of GFU 5 (trench H), set chronologically between *ca.* 80 and 51 ka, the predominant type of quartz still is J11 (n = 2637/3869).

In addition, a peak (n = 232/ 3869) in the amount of glossy white quartz (J18) corresponds to this stratigraphic interval, with a normal distribution ending at AU 19. After this unit this quartz variant becomes residual. The exploration of this raw material is notably related to the production of short quadrangular flakes (fig. 5).

In these artificial units, the discoid and *Levallois* knapping methods are still frequent, however, cores and flakes produced through prismatic knapping strategies, as well as more expeditious ones, were also retrieved in higher quantities. The recourse to bipolar on anvil technique has also been documented, although in small frequency.

Uma imagem com comida

Descrição gerada automaticamente

**Figure 5.** Width/ thickness (mm) of blanks and tools of AU 31-23 of area H’/I’-17/19 with photographic detail of blanks obtained in J18 type of quartz: GFU 5 AU 24 (5 and 6), AU 25 (1, 3 and 8), AU 26 (2 and 7), AU 28 (4) and AU 30 (9). Photo © Fernando Barbosa.

Comparatively, the knapping remains from AUs 19-10 (GFU 5, trench H), dated between 51 ka and 39 ka, were mainly produced in J9 type of quartz (n = 2579/3281) (fig. 4). The presence of J18 is residual (n = 5/3281) and in relation to the older units the amount of quartzite (K2) (n = 19/3281) and translucid rock crystal (J13) (n = 48/3281) increases slightly (in AUs 38-20, the amount of K2 was of 15/3869 and the amount of J13 was of 24/3867).

Despite the continuity in the adoption of discoid and prismatic reduction strategies in these levels, as well as less formalised ones, no diagnostic *Levallois* products were found in these layers (tab. 1; fig. 6).

Uma imagem com Mineral, rocha, Ferramenta de pedra, pedra

Descrição gerada automaticamente

**Figure 6.**  Blanks from area H’/I’-17/19: **1.** **H’17B, GFU5 AU14**. This is a core edge flake or éclat *debordant*. It is J9 type of quartz, complete, has no cortical surface, presents extractions scars oblique to the technological axis; **2. H’17D, GFU5 AU16**. This flake, complete and has no cortical surface, presents extractions scars with the same direction of its technological axis and a flat platform. The type of quartz is J11; **3. I’16, GFU5 AU16**. This flake is complete, has no cortical surface, the direction of the previous extraction is the same as its technological axis and the platform is facetted. The platform angle is 90°, which could explain its reduced size. J11 type of quartz; **4.** **H’17 B, GFU5 AU19**. This is a proximal fragment of a flake obtained from a discoid core. It has no cortical surface and a flat platform. The scars on the dorsal face are oblique to its technological axis. J11 type of quartz; **5.** **I’18, GFU5 AU25**. This flake is complete and has no cortical surface. The extraction scars on the dorsal face have the same direction as its technological axis and the platform is facetted. J18 type of quartz.

In AUs 15-10 of trench Z, all the retrieved knapping remains were made in quartz, specially the J9 variant (n = 131/171). We also found discoid cores and blanks obtained through the application of this method (fig. 7). Similarly, in AUs 18-11 of trench N the predominant raw material is the J9 type of quartz (n = 791/1381), but quartzite (K2) (n = 3/1381) and rock crystal (J13) (n = 18/1381) are also present in residual quantities (fig. 4). Furthermore, products associated to discoid debitage were found in these levels.

The similarities between these units of trench Z (AUs 15-10) and N (AUs 18-11) with the upper section of the sequence of trench H (AUs 19-10) suggest they might belong to the same chronology ( ̴51-39 ka).

Uma imagem com esboço, desenho, Desenho de linha, ilustração

Descrição gerada automaticamente

**Figure 7.** Some cores and core edges from the sample: 1. H’17 GFU5 AU27 (1), N’15 GFU5 AU12 (2), Z8 GFU5 AU15 (3), Z8 GFU5 AU11 (4).

Now, regarding AUs 9-6 of trench Z and AUs 10-8 of trench N, the raw material mostly used is J9 type of quartz (in Z area n =113/157 and in N area n = 389/872) (fig. 4). In these levels there is a slight increase in quartzite (K2) (in Z area n = 7/157 and in N area n = 45/872) and rock crystal (J13) (in Z area n = 3/157 and in N area = 30/872), but also flint and silcrete appear in small amounts (in Z area n = 1/157 and in N area n =14/872).

The most frequent knapping strategies among the lithic remains of these layers are prismatic unipolar and between 77 % (trench N) to 95 % (trench Z) of the blanks have unipolar scars (tab. 3 to 8); also 2/3 prismatic cores of trench N (out of 6 cores in total) were explored through unipolar strategies as was the only core retrieved in trench Z). Also, small blanks are prevalent, especially in rock crystal (J13) and quartzite (K2) (fig. 9 and 10). In AU 8 of trench N, we found a prismatic core in this raw material, with two natural opposed surfaces, one of which was used as a platform (fig. 8). During the knapping sequence, the knapper took advantage of the lateral convexity of the cobble to produce short flakes with two parallel sharp edges. This strategy had not been documented before, in fact, the prismatic cores from older units did not appear as formalised. On the other hand, cores with a similar exploration were retrieved from GFU 4 and GFU 4b of the site, dated from the Upper Palaeolithic. In addition, a bipolar on anvil core in rock crystal (J13), weighing 0.5 g, was recovered from AU 9, which also resonates with the archaeological remains found in GFU 4 and GFU 4b.

Uma imagem com Mineral, rocha, Ferramenta de pedra, natureza

Descrição gerada automaticamente

**Figure 8.** Prismatic core in quartzite (K2) from O15C GFU5 AU8.

Lastly, a significant part of the artefacts from AUs 5-1 of trench Z are associated with the production of elongated small blanks and bladelets, which is apparent by their dimensional distribution (fig. 11). Furthermore, there is a slight increase in flint and silcrete in these layers (n = 4/1109) and of different quality/ geological origin (types D1/2, H2 alongside type I1, which had been documented in AUs 9-6).

**Uma imagem com texto, captura de ecrã, file, diagrama

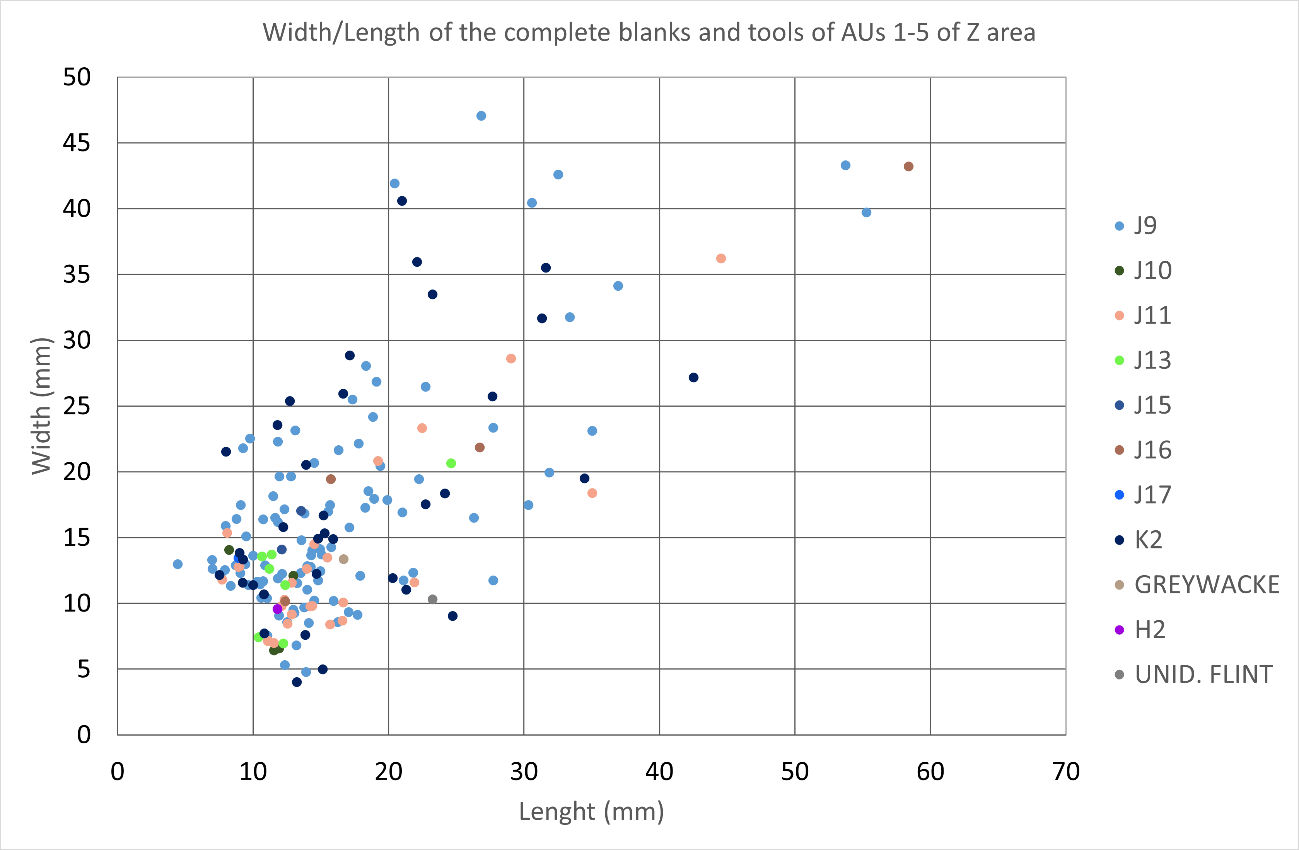
Descrição gerada automaticamente**

**Figure 9.** Thickness/ width (mm) of the complete blanks and tools of AUs 18-11 of N area.

Uma imagem com texto, captura de ecrã, diagrama, file

Descrição gerada automaticamente

**Figure 10.** Thickness/width (mm) of complete blanks and tools of AUs 10-8 of N area.



**Figure 11.** Length/ width (mm) of complete blanks and tools of AUs 5-1 of area Z/A’-6/8.

**Discussion**

Through typo-technological analysis we were able to ascribe the assemblages of GFU 6/7 and GFU 5 (AUs 38-10 of trench H, AUs 15-10 of trench Z and AUs 18-11 of trench N) to the Neanderthal-associated Middle Palaeolithic lithic technology. However, some technological differences and others pertaining to raw material management, when conjugated with the absolute dates obtained for the deposits, suggest that there are at least three different groups of lithic assemblages within this chrono-cultural period.

GFU 6/7 have been dated from 155 ka (GFU 7) to before *ca.* 80 ka (date obtained for the bottom of GFU 5). The artefacts uncovered in these units show that, during this time, discoid and *Levallois* knapping strategies were being used, but also that there was an investment in the production of some large blanks and tools. Moreover, quartz was the most explored raw material, in particular the J11 type, but also rhyolite (J15) and quartzite (K2) were tinkered with.

Comparatively, the lithic industries of AUs 38-20 of GFU 5 of the H area, which correspond to a time interval between *ca.* 80 ka and 51 ka, testify to an occupation phase when the discoid and *Levallois* methods remained important alongside other knapping strategies such as prismatic reduction, which was neatly associated with the use of J18 type of quartz. Nevertheless, J11 was still the most employed variant of this mineral. As mentioned before, J18 has been identified as a variation of J10 and J11 type of quartz when heated [14], so the fact that the amount of knapping remains in J18 is the highest in this AU group, where the J11 type of quartz is predominant, suggests that there is a technological relationship between both distributions. It should be noted, however, that J11 type of quartz was already the most representative raw material in the older levels, where the J18 category is unknown.

Regarding AUs 19-10 of trench H, AUs 15-10 of trench Z and AUs 18-11 of trench N, probably situated between 51 ka and 39 ka and hence belonging to a recent phase of occupation during the Middle Palaeolithic, the knapping remains comprise mostly products obtained through discoid and prismatic reduction strategies, with no unequivocal indication of the *Levallois* method having been employed. Throughout this time, the most used type of quartz was J9.

All the raw materials explored during these phases of the Middle Palaeolithic are of local origin, available near or a few kilometres from the site [14]. The fact that quartzite (K2) was not used as frequently strikes as odd, mostly because it is available in secondary position in or near the riverbed.

In upper artificial units of GFU 5, namely AUs 9-6 of trench Z and AUs 10-8 of trench N, dated after 39 ka, some evidence appears to indicate that these levels have been disturbed and that the assemblages that were retrieved therein are composed of materials belonging to different chronologies, i.e. dated from the Middle Palaeolithic and Upper Palaeolithic. The raw material distribution shows a gradual progression in the percentages of lithic resources that are insignificant in the lower levels and gain expression in the most recent ones. Furthermore, the quartzite (K2) core retrieved from unit AU 8 of area N bears resemblance to others recovered from Gravettian occupations of the site [20] and levels K/ L of Gruta do Caldeirão (Tomar), also attributed to the Gravettian [38]. The recovered bipolar on anvil core in rock crystal (J13) is small compared to the one found in Middle Palaeolithic units of area H, and this technique, as well as raw material, were both used and explored during the Gravettian occupation of the site [20].

This mixture of artefacts could be explained by a sedimentary unconformity due to erosional processes or even low energy remobilization of materials associated with flooding events of the Côa river [21].

On the other hand, the assemblages of units AUs 5-1 of trench Z show Upper Palaeolithic technological characteristics, namely a high number of elongated small blanks and bladelets, but also higher percentages of flint and silcrete. These aspects have been documented in knapping remains belonging to the Upper Palaeolithic from Cardina-Salto do Boi and elsewhere in the Côa Valley [20, 39].

However, the study of trench Z must be completed in order to confirm this interpretation.

Despite that, it seems clear that neanderthal groups who inhabited the Côa Valley between 155 ka and 39 ka relied on a lithic resource economy based on the exploration of raw materials available locally and for them the characteristics of quartz, which have caused researchers to underrate it, if ever a problem, were never an impediment.

This same adaptability has been documented in Figueira Brava, a coastal cave situated in Setúbal, centre west of Portugal [13]. At this site, neanderthal occupation spans from 106 ka to 86 ka and the main raw material of the assemblages is quartz (> 80%). Surprisingly, as it happens at Cardina-Salto do Boi, quartzite and limestone were not used as frequently despite being available relatively close to the site [13].

In the earlier phases of occupation, centripetal knapping strategies were mostly employed along with the Kombewa and *Levallois* methods. But after *ca.* 90 ka, other reduction strategies were added to the repertoire, namely the bipolar on anvil technique and the S. S. D. A. method [13]. The abundance of quartz made for the expeditious character of many of the centripetal cores [13]. It should be noted that whenever the cores were not obtained through the exploration of previous blanks, cobbles were used.

This is not the case at Cardina-Salto do Boi, where blocks were almost always employed.

Therefore, it would appear that the morphology of raw materials was an influencing factor in the choice of knapping methods, with the angular nature of blocks rendering them more suitable for strategies other than the Kombewa and bipolar on anvil ones, for instance.

At Cova Eirós too, in Triacastela municipality of Galicia, Spain, quartz was the mainly used lithic resource. Discoid and *Levallois* methods have been documented in the lower levels and their employment lasted until the Aurignacian [11]. The Kombewa reduction was only identified in the most recent level attributed to the Mousterian, as is also the case at Cardina. But, contrary to Cova Eirós, at Cardina the *Levallois* method appears to have not been used at this time. Unfortunately, a matter with the dates doesn’t allow for a more refined comparison [11].

What seems interesting, regarding Cardina-Salto do Boi assemblages and the more recent phase of occupation, is that from 51 ka onwards the J9 variant of quartz was the most employed. As mentioned before, the J9 type of quartz distinguishes itself from the J11 type or J10 for being opaque and coarsier, but more readily available. It could be a matter of accessibility, as happened at Calvero de la Higera [7].

Regardless, the wide range of knapping strategies that were adopted to make the most out of the available lithic resources, namely quartz, proves that there was and is more to this raw material than previously thought.

**Concluding remarks**

We would like to conclude that the review of the archaeological materials we did has contributed to our understanding of Cardina-Salto do Boi site, namely its formation and occupations, but to confirm our interpretations we need to complete the revision of the archaeological materials both qualitatively and quantitatively.

Furthermore, it would be interesting to assess the mechanical traces of the archaeological materials as well as insist on refitting materials of adjacent squares or units in order to better understand the taphonomy of areas Z and N and avail the importance of depositional disturbances in the formation of the respective assemblages. Studies of this nature have shown very interesting results and contribute greatly to a holistic approach better supported by evidence [40, 41].

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**Conflict of interest disclosure**

The authors declare that they comply with the PCI rule of having no financial conflicts of interest in relation to the content of the article.

**Data, scripts, code, and supplementary information availability**

Data or any supplementary material are available at <https://osf.io/apnzf/> .

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