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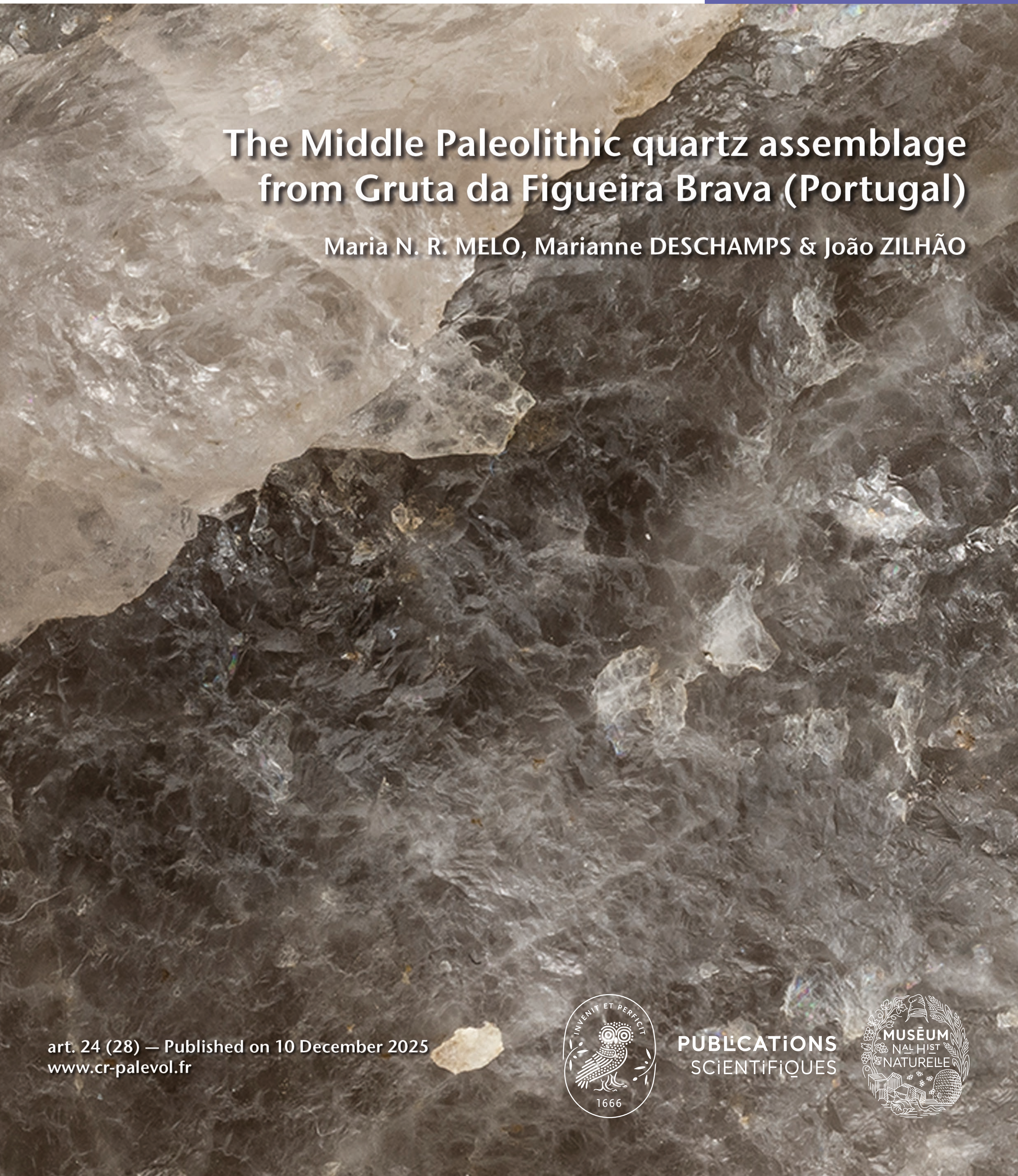

The Middle Paleolithic quartz assemblage from Gruta da Figueira Brava (Portugal)

Maria N. R. MELO, Marianne DESCHAMPS & João ZILHÃO

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The Middle Paleolithic quartz assemblage from Gruta da Figueira Brava (Portugal)

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ABSTRACT
For the understanding of Middle Paleolithic subsistence behaviors, Gruta da Figueira Brava (Setúbal, Portugal) is a key site, as it represents the earliest evidence of systematic subsistence exploitation of marine resources in Europe known to date. However, the associated lithic assemblage, more than 80% composed of quartz, has so far remained understudied. Although widely used during the Pleistocene and the Holocene, quartz, the most abundant mineral on Earth, has been traditionally considered as a "second-rate" resource. Due to the raw material's specific fracture mechanics, quartz lithic assemblages have the tendency to be typologically and morphologically less standardized than flint ones. For these reasons, studies of quartz assemblages have been few and far between, especially when flint and quartzite ones, easier to analyze, are found alongside. Following techno-typological and techno-economic approaches, we carried out a study of a sample of quartz cores and blanks from three successive Figueira Brava human occupation phases spanning the 86-106 ka (thousands of years ago) interval. The results show that several reduction methods were successfully applied, displaying good management of the mechanical properties of the raw material. Alongside the Bipolar-on-Anvil technique, methods such as Levallois and Discoid were used, albeit following strategies somewhat different than with flint and quartzite. At Figueira Brava, the use of quartz – abundant locally and skillfully worked through a diverse range of reduction methods – reflects the good adaptation of the cave dwellers to their environmental context.

KEY WORDS
Neanderthal,
quartz,
lithic technology,
MIS 5.

RÉSUMÉ
L'industrie du Paléolithique moyen en quartz de la grotte de Figueira Brava (Portugal).
Pour la compréhension des comportements de subsistance au Paléolithique moyen, la grotte de Figueira Brava (Setúbal, Portugal) est un site-clé, représentant la plus ancienne preuve d'exploitation alimentaire systématique des ressources marines connue à ce jour en Europe. Cependant, l'assemblage lithique, composé à plus de 80 % de quartz, est resté peu étudié jusqu'à récemment. Bien qu'il soit le minéral le plus répandu sur Terre, utilisé par différentes technologies lithiques au cours du Pléistocène et de l'Holocène, le quartz a été traditionnellement classé comme une ressource de second rang. En raison d'une forte tendance à la fracturation, les assemblages lithiques en quartz sont typologiquement et morphologiquement moins standardisés que ceux en silex. Pour ces raisons, les études concernent les industries en quartz restent rares, surtout lorsqu'elles sont associées au silex et au quartzite, qui sont plus faciles à analyser. En suivant les approches techno-typologique et techno-économique, nous avons effectué l'étude d'un échantillon de nucléus et de produits en quartz provenant de trois phases successives d'occupation humaine de Figueira Brava couvrant l'intervalle entre 86 et 106 ka (milliers d'années avant le présent). Les résultats montrent que différentes méthodes de taille ont été appliquées avec succès, ce qui implique une bonne gestion des propriétés mécaniques particulières de la matière première. Les méthodes Levallois, Discoïde, et Bipolaire-sur-Enclume ont été utilisées et différentes stratégies techno-économiques peuvent être mises en évidence par rapport à l'industrie en silex et en quartzite. À Figueira Brava, l'utilisation du quartz, abondant localement et taillé grâce à diverses méthodes de débitage, reflète la bonne adaptation des habitants au contexte environnemental du site.

MOTS CLÉS
Néandertal,
quartz,
technologie lithique,
MIS 5.

INTRODUCTION

Research background

Quartz, silicon dioxide (SiO_2), is the most common mineral on Earth and a major component of many igneous, sedimentary, and metamorphic rocks (Driscoll 2010). Because of its abundance in the landscape and durable edge properties (e.g. Abrunhosa *et al.* 2019) or for symbolic reasons (de Lombera-Hermida & Rodríguez-Rellán 2016), quartz was widely used by prehistoric communities (Mourre 1996; Bracco 1997; Jaubert 1997; Knutsson & Lindgren 1999). Despite its widespread representation in the archeological record, the analysis and classification of quartz artifacts have been particularly challenging for archaeologists, due to what Callahan (1987) defined as the "gravel effect" – the perception of most quartz products as amorphous, not easily recognizable as human-modified. This has led to quartz industries becoming out of favor with the scientific community, which has overwhelming focused on flint ones (Mourre 1996; Knutsson & Lindgren 1999). The prevalence of "flint-thinking" in prehistoric archaeology (Knutsson 2014) has fostered the perception that quartz was primarily employed only when higher-quality raw materials, such as flint, were unavailable. This perception gave rise to the Flint-for-Levallois versus Quartz-for-Discoid dichotomy that has been advocated for the Middle Paleolithic of France, a region where flint is naturally abundant (Boëda 1994).

It was only from the 1970s onwards, with the emergency of novel analytical approaches, namely the *chaîne opératoire* approach, that researchers began to fully consider the range of knapping strategies used by Middle Paleolithic people in the context of the diverse environmental constraints that they faced. The observed variation came to be understood as the result of multiple factors: production requirements and site function; raw material availability; the lithology, size, and crystalline properties of the starting volumes (e.g. presence or absence of fissures and cleavage planes); and the technological knowledge of the knappers (Rolland & Dibble 1990; Delagnes & Meignen 2006). This shift in perspective moved the focus away from direct, flint-based comparisons to uncovering the technological logic behind non-flint lithic raw material usage, especially in areas where quartz is more common than flint, such as Scandinavia (Knutsson *et al.* 2016) or Northwestern and Central Iberia (Pereira & Benedetti 2013).

It was with the development of systematic experimental studies (e.g. Tixier 1978; Texier 1981), the pioneering studies in Scandinavia (Knutsson & Lindgren 1999; Saville & Ballin 2008), and the opening up of new fields of research in Africa, where flint played a secondary role (Mourre 1996), that the study of quartz industries gained the role it deserves. More recently, renewed methodological approaches (e.g. de Lombera-Hermida & Rodríguez-Rellán 2016; Knutsson *et al.* 2016; Manninen 2016; Pargeter & de la Peña 2017; Daffara 2018; Pargeter *et al.* 2019; Spry *et al.* 2021; Yeşilova *et al.* 2024), along with the analysis of previously unstudied assemblages (e.g. Muñoz del Pozo *et al.* 2023; Ramos *et al.* 2024; Daffara *et al.* 2025), have improved our understanding of quartz lithic technology and led to the development of analytical criteria better suited to its petrographic and mineralogical characteristics.

In this context, we present Gruta da Figueira Brava (Setúbal, Portugal) as a case study of quartz use in the Middle Paleolithic of the Iberian Peninsula. The lithic assemblage from an earlier phase of fieldwork has been analyzed (Cardoso & Raposo 1993; Raposo & Cardoso 2000), but publication of the stone tools from the most recent excavations (2010-2013) remains partial: it concerns the flint component plus the use-wear

FIG. 1. — **A**, Location of the cave in the Serra da Arrábida (Setúbal, Portugal); **B**, overview of its three extant entrances (after Zilhão *et al.* 2020).

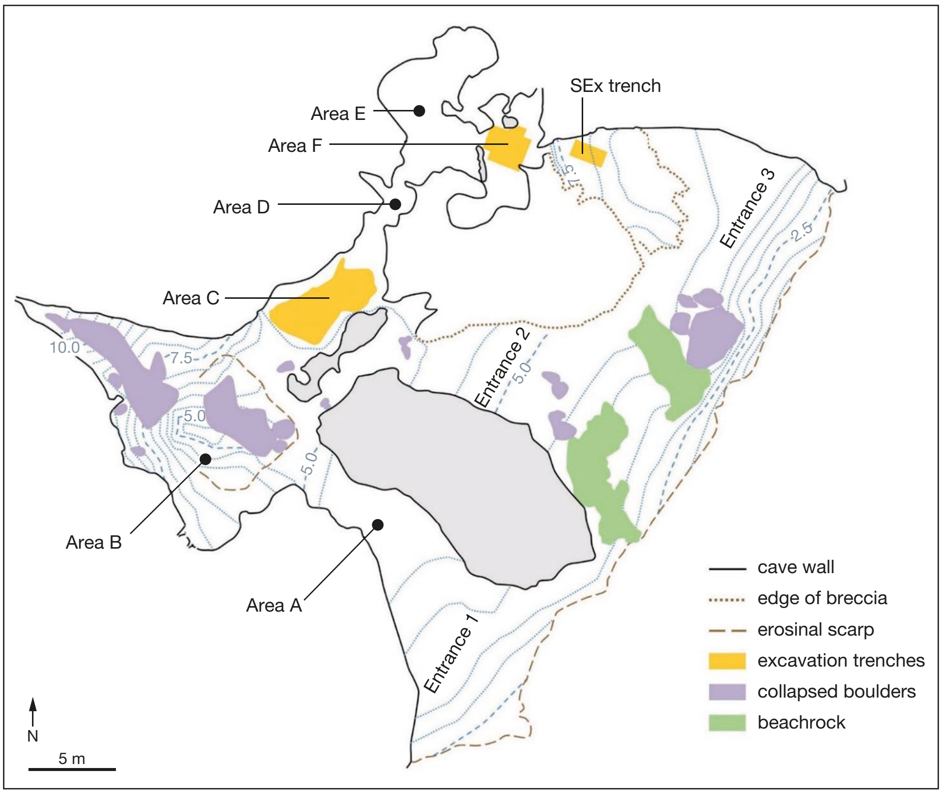

FIG. 2. — Site plan with position of the excavated trenches (after Zilhão *et al.* 2020). Elevations are given in meters above sea level.

analysis of a small sample of 50 quartz items (Zilhão *et al.* 2020). Here, we summarize the results of a techno-typological study conducted on a sample of the quartz assemblage (Melo 2023). Our findings, alongside those made at other Iberian sites, support the idea that quartz is a versatile raw material amenable to exploitation via complex debitage strategies such as the Levallois and Discoid methods.

SITE DESCRIPTION AND STRATIGRAPHIC INFORMATION

The Figueira Brava cave (38°28'14"N, 8°59'10"W, WGS84) is located on the Arrábida coast, south of Lisbon (Fig. 1). It was first described in 1945 by H. Breuil and G. Zbyszewski, who mention the presence of lithic artefacts and Quaternary faunal remains (Breuil & Zbyszewski 1945; Cardoso & Raposo 1993, 1998). In its current configuration, the site has three

Area C (1989-1989)	Entrance 3 (2010-2013)	Area F (2010-2013)	Human occupation	Chrono-stratigraphy
2a	–	IT0	–	Reworked
0		IT2		Holocene
		IT1		MIS 2-MIS 5a
1	UC1	IH1		
2	UC2-UC6	IH2	Phase FB4	MIS 5b (86.0 to 90.0 ka)
		IH3		
		IH4		
		IH5		
		IH6		
		IH7		
		IH8		
3	MC0	IL1	Phase FB3	MIS 5c (92.0-94.0 to 104.0-106.0 ka)
	MC1-MC2	IL2		
		IL3		
	MC3-MC5	–	Phase FB2	
4	LC1-LC3		Phase FB1	
5	CO	IB1	–	MIS 5c-MIS 6
–	–	IB2		MIS 6 or older

Fig. 3. — Stratigraphic correlation scheme: equivalence between the stratigraphic units of the different areas, occupation phases, chronology, and positioning in the Marine Isotope Stage (MIS) sequence. After Zilhão *et al.* (2020), modified.

entrances (1, 2 and 3) and its interior has been subdivided into six distinct areas (A, B, C, D, E, and F; Fig. 2) (Zilhão *et al.* 2020). The interior area accessed through Entrance 1 (Areas A and B) has been heavily eroded, but the Pleistocene infilling has been preserved in Entrances 2 and 3 and adjacent interior areas (Areas C and F, respectively).

The site was first excavated in the 1980s, when Areas B and C were targeted. Almost four thousand lithic artifacts, including mainly quartz and, secondarily, flint and quartzite artefacts, homogeneously attributed to the Middle Paleolithic, were retrieved alongside a Neanderthal tooth and a wide range of faunal remains, including an important marine resource component (Cardoso & Raposo 1993; Antunes & Cardoso 2000; Raposo & Cardoso 2000). A conventional radiocarbon measurement on a bulk sample of limpet shells collected in layer 2 of Area C (lCEN-387) yielded an age of 30 930 ± 700 BP (*c.* 35 ka) for this context (Cardoso & Raposo 1998).

As demonstrated by Zilhão *et al.* (2020), that radiocarbon result is a vast underestimate of the sample's age, which is due the age of the shells lying beyond the method's limit of applicability and the attendant impact of even very small amounts of unremoved contaminants. The correct age of the sequence is based on uranium-thorium (U-Th) and optically stimulated luminescence (OSL) dating of stratigraphically associated speleothems and of the sediments themselves, respectively. This work was carried out in the context of the 2010-2013 excavations of Entrance 3 and Area F, shed new light on the site's stratigraphic layout, and moved the time of human occupation back to the interval of 86-106 ka, in Marine Isotopic Stages (MIS) 5b and 5c (Fig. 3). This work's wider behavioral significance, however, rested on its demonstration that Neanderthal coastal populations of the Last Interglacial exploited marine resources as much as coeval (e.g. South African) or later (e.g. Atlantic European Mesolithic) "modern human" ones (Zilhão 2012; Zilhão *et al.* 2020).

Our analysis here uses the four-phases framework of Zilhão *et al.* (2020). These phases correspond to intervals during which the conditions of formation of the stratigraphic units remained similar at all scales (local, regional, topographic, environmental). Phase FB1 corresponds to the LC complex of Entrance 3; it was not represented in the excavated trenches and is only known through exposures observed along the seaward edge of the erosion-truncated infilling of that area. The sample that we report on is comprised only of finds belonging to the FB2, FB3 and FB4 phases. The FB2 and FB3 sediments were brecciated; their excavation required the use of power tools, namely demolition hammers, and the (inevitable) breakage and loss of smaller items that occur in these circumstances must be kept in mind when these phases' content is compared with FB4's.

Coastal zones are ecotones where marine, estuarine, and terrestrial habitats converge to produce some of the ecologically richest places on the planet (Haws *et al.* 2010, 2011; Brown *et al.* 2011). They offer plenty of easily exploitable resources, including mollusks, crustaceans, echinoderms, marine mammals, fish, birds, and plant foods (e.g. pine nuts), all of which are abundantly represented in the Figueira Brava deposit. Given its privileged location, it is not surprising that human usage of the cave extended over such a long period of time.

The lithic artefacts retrieved from the site are predominantly made of quartz. Flint, quartzite, and limestone are found less frequently (Table 1), while other raw materials, such as jasper, rhyolite, and lydite, are present in very small amounts.

RESEARCH CONTEXT AND KEY QUESTIONS

Due to its hardness and its mechanical and physical properties, vein quartz was commonly used to produce stone tools, via a range of technological systems, all through the Pleistocene and the Holocene (Mourre 1996; Bracco 1997; Jaubert 1997; Knutsson & Lindgren 1999). However, in the absence of clear definitions of which features specific to quartz are indicative of how reduction proceeded from initial volume to end product, criteria based on the study of flint collections are routinely applied to quartz, generating classificatory confusion and further complicating technological analysis (de Lombera-Hermida 2009; Driscoll 2011; Knutsson *et al.* 2016; Rodríguez-Rellán 2016).

The traditional underrating of quartz as a secondary resource, only used in cases of local unavailability of flint, has mostly been based on the following arguments:

– typologically and morphologically, quartz assemblages are less standardized than flint ones due to the raw material's proclivity to fracture and lower resistance to compression and traction, leading to less well-defined flaking planes (Mourre 1996; Driscoll 2011; de Lombera-Hermida & Rodríguez-Rellán 2016);

– quartz often features internal flaws and microfractures due to post-formation processes (de Lombera-Hermida & Rodríguez-Rellán 2016);

– being less prone to conchoidal fracturing, quartz tends to break unpredictably along internal fissures, radially and transversely (Spry *et al.* 2021).

Here, based on the analysis of Figueira Brava's lithic assemblage, we show that these features of the raw material do not stand in the way of its productive and efficient exploitation for stone tool making. In addition, we also address the following questions of more general interest:

– does a particular lithological setting condition the organization of the technology of past humans, i.e., is the geological environment the only determinant of the recourse to quartz, or are there other circumstances that also require consideration?

– how much and in which way do the mechanical and petrographic properties of quartz affect the organization and management of reduction sequences?

– what technological strategies were used to overcome the limitations associated with the knapping of vein quartz, and did such strategies change over time?

– was quartz, at least in some cases, preferred over flint and, if so, why?

– did raw material selection change over time (e.g. were quartz, quartzite, and flint always used in similar proportions and for similar purposes)?

– what kinds of blanks and formal tools were produced, and is there change over time or relative to raw material selection?

MATERIAL AND METHODS

We used a techno-economic approach (Geneste 1985): every stage in the production of lithic artefacts is situated within a specific temporal and spatial context, from the acquisition of raw materials to their ultimate discard (Leroi-Gourhan 1964; Geneste 1991). The first step is the identification of potential supply areas, specific sources, and modes of introduction. The second step is the technological analysis of the cores and flakes to reconstruct the *chaînes opératoires* (Leroi-Gourhan 1964; Tixier 1978; Geneste 1985; Inizan *et al.* 1999). The third step is the typological classification (Inizan *et al.* 1999; Bordes 2000) of the retouched products, accompanied by an analysis of blank selection.

Our study was carried out on a sample comprised of different raw materials (flint, quartz, quartzite, limestone) totaling 1094 artifacts (Table 1) and corresponding to almost 30% of the total (excluding debris and unmodified blocks and unmodified cobbles, N = 3846). The analyzed sample comes from the SEx trench, which illustrates the FB2 phase, and from two squares (T8 and U8) of the Area F trench representative of phases FB3 and FB4. For the technological analysis of the assemblage, an Excel database was created. The different technological features considered (see Raw material: types and alterations and Technological description below) were meant to ensure that comparison between the different phases of Figueira Brava's occupation was based on the same descriptive and interpretative criteria.

Raw material: types and alterations

For each artefact, we determined the raw material properties potentially underpinning the choice of reduction technology or the morphology of extracted blanks: type, volume morphology, and presence/absence of thermoalteration.

Traditionally, quartz has been divided into two main subcategories: vein quartz, commonly referred to as milky quartz, and hyaline quartz, widely known as rock crystal (Mourre 1996). In certain instances, especially when dealing with high-quality and diverse samples, further distinctions can be made based on lithological characteristics. In archaeological assemblages, the described variants have included greasy quartz, coarse-grained quartz, and wind-blown quartz (Ballin 2008; Saville & Ballin 2008). However, this classification does not consider the mineralogical properties and formation processes, which have significant implications for chemical composition and

TABLE 1. — Composition of the studied stone tool assemblage. "Others" includes lydite (N = 1), rhyolite (N = 1), and jasper (N = 1).

		Cores	Flakes	Tools	Debris	Hammerstones/Anvils	Manuports	Total
FB2	**Quartz**							
	N	26	54	7	–	–	–	87
	%	24.1%	50%	6.5%	–	–	–	80.6%
	Flint							
	N	–	10	–	5	–	–	15
	%	–	9.3%	–	4.6%	–	–	13.9%
	Quartzite							
	N	2	2	1	–	–	–	5
	%	1.9%	1.9%	0.9%	–	–	–	4.6%
	Limestone							
	N	–	–	–	–	–	–	–
	%	–	–	–	–	–	–	–
	Others							
	N	–	–	1	–	–	–	1
	%	–	–	0.9%	–	–	–	0.9%
	Total (N)	28	66	9	5	–	–	108
	Total (%)	25.9%	61.1%	8.3%	4.6%	–	–	100%
FB3	**Quartz**							
	N	53	58	12	13	–	–	136
	%	32.5%	35.6%	7.4%	8.0%	–	–	83.4%
	Flint							
	N	1	6		4	–	–	11
	%	0.6%	3.7%		2.5%	–	–	6.7%
	Quartzite							
	N	4	2	1	–	–	1	8
	%	2.5%	1.2%	0.6%	–	–	0.6%	4.9%
	Limestone							
	N	–	1	–	–	–	2	3
	%	–	0.6%	–	–	–	1.2%	1.8%
	Others							
	N	1	3	–	–	–	1	5
	%	0.6%	1.8%	–	–	–	0.6%	3.1%
	Total (N)	59	70	13	17	–	4	163
	Total (%)	36.2%	42.9%	8.0%	10.4%	–	2.5%	1005
FB4	**Quartz**							
	N	193	354	96	29	9	5	686
	%	23.6%	43.3%	11.7%	3.5%	1.1%	0.6%	83.9%
	Flint							
	N	8	51	3	17	–	–	79
	%	1.0%	6.2%	0.4%	2.1%	–	–	9.7%
	Quartzite							
	N	1	15	2	2	–	–	20
	%	0.1%	1.8%	0.2%	0.2%	–	–	2.4%
	Limestone							
	N	5	9	–	–	–	4	18
	%	0.6%	1.1%	–	–	–	0.5%	2.2%
	Others							
	N	–	10	2	3	–	–	15
	%	–	1.2%	0.2%	0.4%	–	–	1.8%
	Total (N)	207	439	103	51	9	9	818
	Total (%)	25.3%	53.7%	12.6%	6.2%	1.1%	1.1%	100%
Uncertain	**Quartz**	2	2	1	–	–	–	5
All	Total (N)	296	577	126	73	9	13	1094
	Total (%)	27.1%	52.7%	11.5%	6.7%	0.8%	1.2%	100%

fracture mechanisms (de Lombera-Hermida & Rodríguez-Rellán 2016). In this regard, the subdivision in morphostructural types is a useful way to understand the technological choices made by prehistoric communities, as it shows how internal fissures and texture play an important role in raw material selection (de Lombera-Hermida 2009; de Lombera-Hermida *et al.* 2011).

Table 2. — Figueira Brava: lithological categories of the quartz assemblage (three technologically undetermined specimens were not considered).

Subtypes of anhedric milky white quartz (type J9 of Aubry *et al.* 2016)		N	%
J9.1	Homogeneous	376	41.3%
J9.2	More crystallized, cream to pink quartz	42	4.6%
J9.3	More crystallized, orange to grayish brown quartz	6	0.7%
J9.4a	Milky to opaque gray, with some orange veins quartz	26	2.9%
J9.4b	Milky to opaque, spotted gray quartz	11	1.2%
J9.4c	Milky, grainy color (gray or pink) spotted beige quartz	29	3.2%
J9.5	Milky to translucent white quartz	85	9.3%
J9.6a	Milky, grainy color (gray or orange), spotted beige quartz	17	1.9%
J9.6b	Milky to smoky beige or gray quartz	25	2.7%
J9.6c	Milky to smoky spotted gray quartz	68	7.5%
J9.7a	Milky "waxy" light gray or beige quartz	28	3.1%
J9.7b	Milky grainy zoned darker gray quartz	18	2.0%
J9.7c	Milky grainy white, gray or beige quartz	83	9.1%
J9.7d	Milky grainy to vitreous with gradient color change beige to white or gray to white quartz	97	10.6%
Total		911	100%

Nevertheless, considering that vein quartz presents a high degree of internal variability, its subdivision in only four morphostuctural groups, cannot, alone, fully describe the different subtypes of quartz observed in Figueira Brava's lithic assemblage. Hence, for a more comprehensive characterization of the quartz varieties found in the studied assemblage we have adapted the classification proposed for the Cardina-Salto do Boi (Côa Valley, Portugal) case-study (Aubry *et al.* 2016). This classification emphasizes formation processes and composition, allowing a more complete description of quartz's appearance. The categories that we retained, illustrated in Figure 4 and described in Table 2, are based on texture, presence/absence of internal flaws, brightness, degree of transparency, and color of the observed surface.

Criteria for the recognition of burning in quartz artefacts have seldom been reported, described or discussed, but recent experimental studies (Ballin 2008; Driscoll & Menuge 2011) have identified the following: pitting and "peeled-off" surfaces; glossy patina giving the piece an almost polished appearance; alteration of the original color, usually turning it redder or pink, due to the presence of iron oxides; darker, somewhat purplish hue apparent in iron oxide-rich fissures even when the color change is not homogeneous (Fig. 5).

Technological description

For the general description of the attributes of flakes, cores, and tools we followed Inizan *et al.* (1999) and Bordes (1950), with some adaptations due to the raw material's specific constraints (de Lombera-Hermida 2009). For a better classification of debitage methods we followed: Boëda (1993, 1994) and González-Molina *et al.* (2020) for the Levallois and the Discoid methods; de la Peña (2015) and de Lombera-Hermida *et al.* (2016) for Bipolar-on-Anvil

Fig. 4. — Lithological subtypes identified in the Figueira Brava quartz assemblages (representative flakes, and macro views of their surfaces): **A**, J9.1; **B**, J9.2; **C**, J9.3; **D**, J9.4a; **E**, J9.4b; F, J9.4c; **G**, J9.5; **H**, J9.6a; **I**, J9.6b; **J**, J9.6c; **K**, J9.7a; **L**, J9.7b; **M**, J9.7c; **N**, J9.7d. Scale bar: 5 cm.

schemes; Tixier (1978) and Tixier & Turq (1999) for the Kombewa method; and Forestier (1993) for the *système à surface de débitage alterne* (SSDA) method.

In tool classification, we followed a very conservative approach, particularly with regard to notches, as they may be an artifact of post-depositional processes, such as trampling (Thiébaut *et al.* 2010).

RESULTS

Raw material

In the sample studied, quartz corresponds to 83.5% of the total. There is not much variation across the sequence, even though quartz is somewhat less frequent, and flint correspondingly

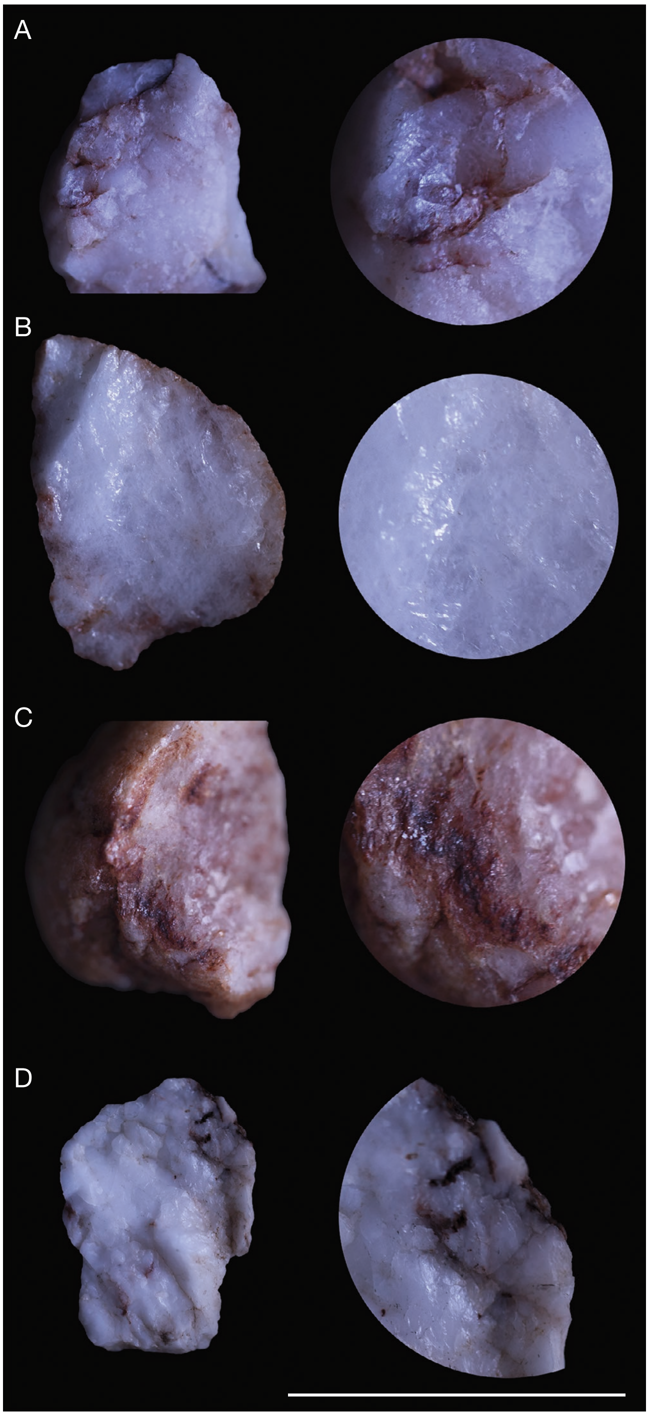

Fig. 5. — Stigmata of burning observed on Figueira Brava quartz artifacts, and macro views of their surfaces: **A**, pitting and "peeling-off"; **B**, glossy patina; **C**, color alteration; **D**, purplish hue of iron oxide-rich fissures. Scale bar: 5 cm.

more so, in phase FB2. In phase FB4 there is also a slightly higher frequency of other types of raw materials, such as lydite, rhyolite, and jasper (Table 1).

Quartz would have been obtained locally, in the form of cobbles, both in marine deposits and in continental conglomerates. Flint came from greater distances – most likely from the right banks of the Tagus, in the Lisbon area, >30 km to the north (Zilhão *et al.* 2020). Like flint, quartzite and limestone also occur in small numbers even though they could have been easily collected nearby, on the terraces of the Sado river and along the coast. Therefore, the high frequency of quartz may reflect deliberate choice, possibly influenced by the immediate abundance and variability of quartz types. Nevertheless, distance to raw material sources must have been only one among several factors influencing raw material selection, exploitation, and curation (Marks *et al.* 1991: 128), which may also have been underpinned by cultural or social factors (Aubry *et al.* 2012), symbolic considerations (de Lombera-Hermida & Rodríguez-Rellán 2016), or adaptive responses to climatic or geological constraints (Pereira & Benedetti 2013).

The quartz varieties in our sample all belong to Aubry *et al.*'s (2016) J9 type of vein quartz. Their physical and mechanical properties impacted the choices made by quartz knappers, as revealed by the following observations:

– the J9.1 subtype – anhedral milky to clear quartz, lacking well-defined crystal faces and shapes – accounts for almost half of the total (41.3%), followed by subtypes J9.7d and J9.5, which account for just 10.6% and 9.3%, respectively. There seems to be no technological or typological justification for this preference. Possibly, J9.1 is simply the most common subtype in the region and the easiest to obtain, a hypothesis that will need to be verified through an actualist study of quartz availability;

– morphostructure, texture, and mineralogy seem to have played an important role. More granular textures – such as those of subtypes J9.4c, J9.6a, J9.7b, J9.7c, and J9.7d – increase elasticity and reduce the occurrence of cracks and fractures (de Lombera-Hermida 2009), thus offering greater knapping control. Not unexpectedly, J9.7c and J9.7d were therefore preferred over less suitable varieties with more internal flaws.

– thermo-alteration is uncommon (25.8%). Considering that evidence for controlled heat treatment on quartz has rarely, if ever, been found (Ballin 2008), we infer that the quartz artefacts whose brightness and color indicate thermoalteration reflect accidental contact with fire.

Cores

Cores represent 27.1% of the sample's techno-economic categories. Their frequency is higher in phase FB3 (Table 1), which the sampling biases caused by the excavation techniques used probably suffice to explain (see Site description and stratigraphic information above). Another factor to consider is variation in the representation of the small flakes (<2 cm) produced when cores were exploited to exhaustion, which were not included in the present study.

Core types are similar across the three phases: centripetal, bipolar, unipolar, prismatic, globular, one-or-two-extraction, and one-surface (Table 3; Fig. 6) and are characterized by an expedient exploitation of the volumes (Binford 1979; Vaquero & Romagnoli 2017). Frequently, their blanks are cortical flakes (Table 4). The exploitation of ventral surfaces was carried out in proximal areas, where a bulb was suitable for producing smaller flakes, and along the entire perimeter of the original blank (Fig. 6A). When the blank was not a flake,

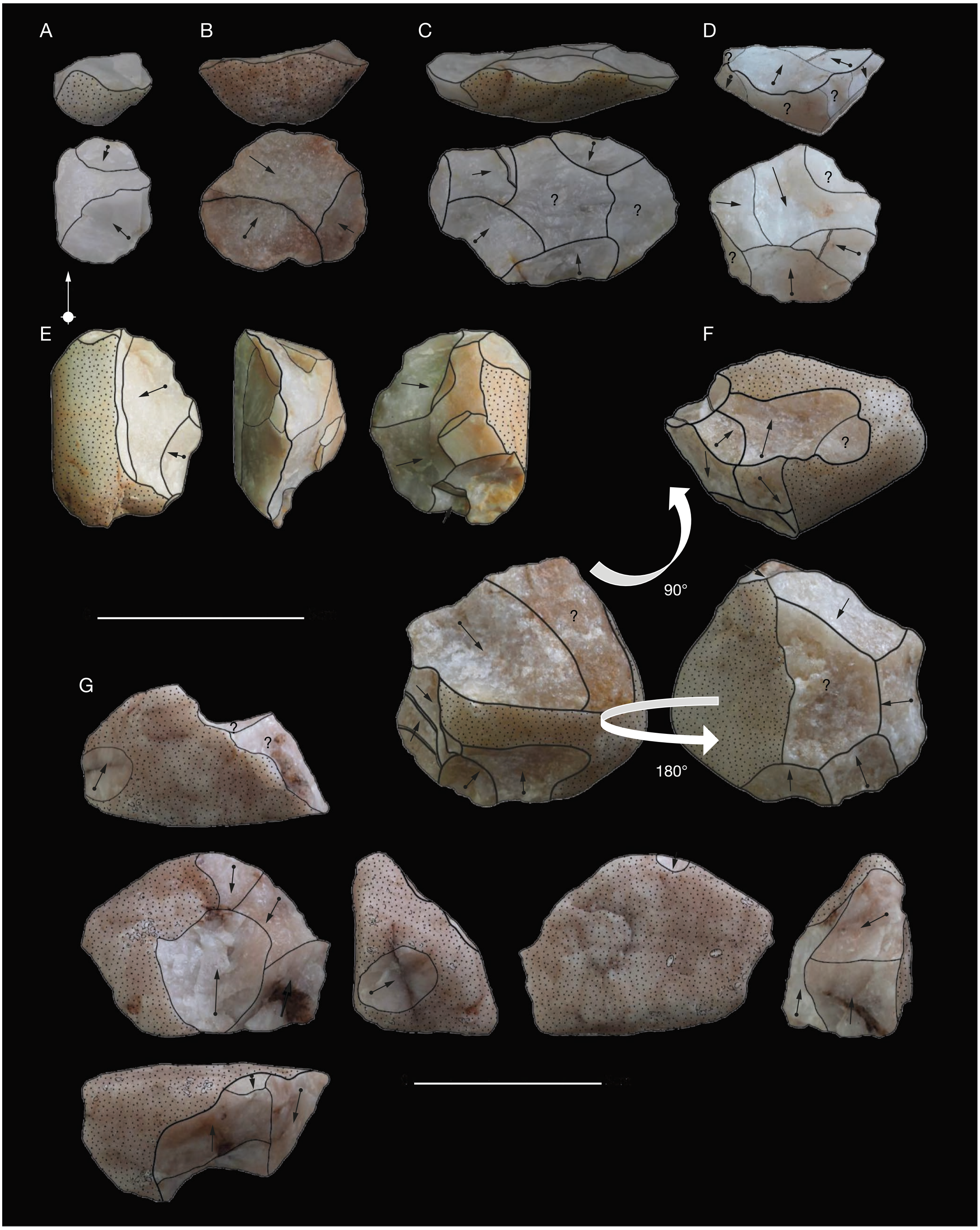

Fig. 6. — Quartz cores: **A**, one-or-two-extraction Kombewa core; **B**, **C**, centripetal cores from FB2; **D**, Levallois core from FB4; **E**, unipolar SSDA core from FB4; **F**, discoidal core from FB4; **G**, Bipolar-on-Anvil core from FB4. Scale bars: 5 cm.

TABLE 3. — Quartz core types.

Core type	Phase FB2	FB3	FB4	Total N	%
Unipolar	1	9	29	39	15.7%
Bipolar	–	4	14	18	7.3%
Centripetal	9	16	57	82	33.1%
Globular	1	4	9	14	5.6%
One-or-two-extraction	9	13	41	63	25.4%
One-surface	3	2	18	23	9.3%
Prismatic	–	1	6	7	2.8%
Atypical carinated	–	–	2	2	0.8%
Total	23	49	176	248	100%
Undetermined	3	4	17	24	–
Total	26	53	193	272	–

TABLE 4. — Quartz core blanks.

Core blanks	Phase FB2	FB3	FB4	Total N	%
Cobble	8	29	78	115	45.3%
Block	–	–	1	1	0.4%
Direct percussion flake	14	17	81	112	44.1%
Bipolar-on-Anvil flake	2	3	17	22	8.6%
Chunk	1	1	2	4	1.6%
Total	25	50	179	254	100%
Undetermined	1	3	14	18	–
Total	26	53	193	272	–

TABLE 5. — Quartz debitage methods (based on cores only).

Debitage method	FB2	FB3	FB4	Total	%
Discoid	1	2	12	15	9.4%
Levallois	2	8	10	20	12.5%
SSDA	–	5	10	15	9.4%
Kombewa	13	13	77	103	64.4%
Bipolar-on-Anvil	–	2	5	7	4.4%
Total	16	30	114	160	100%
Undetermined	10	23	79	112	–
Total	26	53	193	272	–

TABLE 6. — Degree of exhaustion of quartz cores. Grade 1: beginning of life; Grade 2: peak of life; Grade 3: exhausted.

Degree of exhaustion		N	Levallois	%
FB2	Grade 1	11	1	9.1%
	Grade 2	9	1	11.1%
	Grade 3	1	–	–
FB3	Grade 1	24	–	–
	Grade 2	18	6	33.3%
	Grade 3	4	2	50.0%
FB4	Grade 1	77	1	1.3%
	Grade 2	62	4	6.5%
	Grade 3	20	4	20.0%
Total		226	19	–
	Undetermined	46	1	–

neocortical or cortical surfaces were used as striking platforms, taking advantage of appropriate convexities (Fig. 6B, C, E, F) and following an "opportunistic" behavior (Arzarello 2003; Carpentieri & Arzarello 2022). The number of extractions is small, and discard occurs at an early stage of exploitation. Extraction is mostly carried out on one surface only – cores with hierarchically related surfaces are 53.8% (N = 14) in FB2, 47.2% (N = 25) in FB3, and 46.6% (N = 90) in FB4 – and, when determinable, mostly in a centripetal or unipolar manner. Preparation of the striking platform is infrequent and in no way exclusive to debitage methods involving a predetermination of the blank.

Due to the frequent absence of important diagnostic elements – preparation of the striking platform, chronology and organization of scars – inferring debitage methods is challenging and often impossible. When determinable, the most common reduction strategies are Kombewa and Levallois, followed by Discoid, SSDA, and Bipolar-on-Anvil (Table 5). The differences seen across the three phases are minor:

The Levallois concept is more frequent in FB3 (Table 5). FB3's Levallois cores were not discarded at an early stage: all were abandoned either at the peak of their exploitation or at exhaustion (Table 6). To a lesser extent, it's the same in FB4, where most Levallois cores were exploited to exhaustion, with the length of the last removal only exceptionally exceeding 2 cm.

The Discoid method is more frequently identified in FB4, albeit not without some degree of uncertainty (Table 5). This is because the SSDA method, which facilitates long and continuous sequences of removals by automatically maintaining favorable angles between two opposing surfaces, can often lead to scar patterns and core organizations closely resembling those produced by the Discoid method (Mesfin *et al.* 2023). Typologically, the cores assigned to the latter are centripetal, one-surface, globular, or, in a single case, bipolar.

The small size of the sample explains why no FB2 cores display traces of the Bipolar-on-Anvil technique, which, however, is represented among debitage blanks (Tables 7; 8). The Bipolar-on-Anvil cores from the assemblage are mostly exploited following their horizontal axis, in a bipolar rectilinear/convex or single-angular, non-recurrent way, which fits the "Bipolar C" and "Bipolar D" modalities of de Lombera-Hermida *et al.* (2016). In the FB4 phase, one example falls within the so-called bipolar modality on vertical/axial anvil, or "Bipolar E" (Fig. 6G), whereby the cobbles are placed on the anvil along their longest axis and the knapping is parallel, creating a pattern of opposing longitudinal or bipolar extractions. On small and medium volumes, two series of removals are observed, in what seems to be a response to the effects of both the strike and the anvil (de Lombera-Hermida *et al.* 2016). These cores show unifacial series of removals and incipient reduction; they probably reflect the opening-up of spheric cobbles for subsequent, separate exploitation of the parts as blanks for centripetal reduction by the Levallois or Kombewa methods.

At discard, cores are usually small (Fig. 7A), particularly in FB2 and FB4, where they measure <40 mm, which probably is a correlate of the Kombewa method's higher representation.

Table 7. — Quartz flake types.

Flake types	FB2	FB3	FB4	Total	%
<50% cortical flake	8	9	59	76	14.5%
>50% cortical flake	5	3	50	58	11.1%
100% cortical flake	7	5	20	32	6.1%
naturally backed flake (long)	1	3	27	31	5.9%
naturally backed flake (short)	1	3	33	37	7.1%
backed flake	12	12	67	91	17.4%
bipolar	2	1	23	26	5.0%
elongated flake	1	1	12	14	2.6%
regular flake	8	10	60	78	14.9%
perimeter-edged, non-cortical flake	7	13	42	62	11.8%
pseudo-Levallois point	–	–	3	3	0.6%
striking platform flake	1	1	5	7	1.3%
crest flake	1	1	5	7	1.3%
Kombewa flake	–	1	1	2	0.4%
Total	54	63	407	524	100%
flake fragment	6	7	36	49	–
undetermined flake	–	–	1	1	–
Total	60	70	444	574	–

Table 8. — Flaking angles: Figueira Brava (**FB**) compared to the data in Mourre *et al.* (2011) and Kobayashi groups A and C (1979).

	FB All		FB Bipolar-on-Anvil		Kobayashi (1975)		Mourre *et al.* (2011)	
	N	%	N	%	N	%	N	%
75-79°	1	0.2%	–	–	8	3.0%	8	11.2%
80-84°	7	1.6%	3	15.7%	26	9.8%	9	12.7%
85-89°	36	8.4%	12	63.2%	37	14%	13	18.3%
90-94°	91	21.2%	4	21.1%	65	24.6%	14	19.7%
95-99°	78	18.2%	–	–	30	11.4%	12	16.9%
100-104°	82	19.1%	–	–	28	10.6%	10	14.1%
105-109°	58	13.5%	–	–	16	6.0%	4	5.6%
110-114°	35	8.2%	–	–	10	3.8%	–	–
115-119°	28	6.5%	–	–	7	2.5%	1	1.4%
>120°	13	3.0%	–	–	37	14.0%	–	–
Total	429	–	19	–	264	–	71	–

In the final phase of their exploitation, cores only produced small flakes, as indicated by the average size of the last scar (FB2: 17.5 × 22.4 mm; FB3: 21 × 21.9 mm; FB4: 18.2 × 18.4 mm).

Flakes

Flakes correspond to 52.7% of the total lithic assemblage (Table 1). For the techno-typological study, the sample also included flakes corresponding to the preparation stage of the volume, as well as those selected for subsequent retouch.

Regarding flake types, there is no substantial difference between the three occupation phases. The increased diversity, observed across the sequence, is a simple correlate of sample size. Throughout, there is a predominance of semi-cortical flakes, backed flakes, short and long naturally backed flakes, and perimeter-edged, non-cortical flakes (Table 7). Most butts are cortical or unfaceted and most scar patterns are unipolar or bipolar, illustrating exploitation sequences that are mostly expedient (Binford 1979). Flakes with these characteristics can be produced by the Bipolar-on-Anvil technique or the SSDA method. However, the latter produces flakes

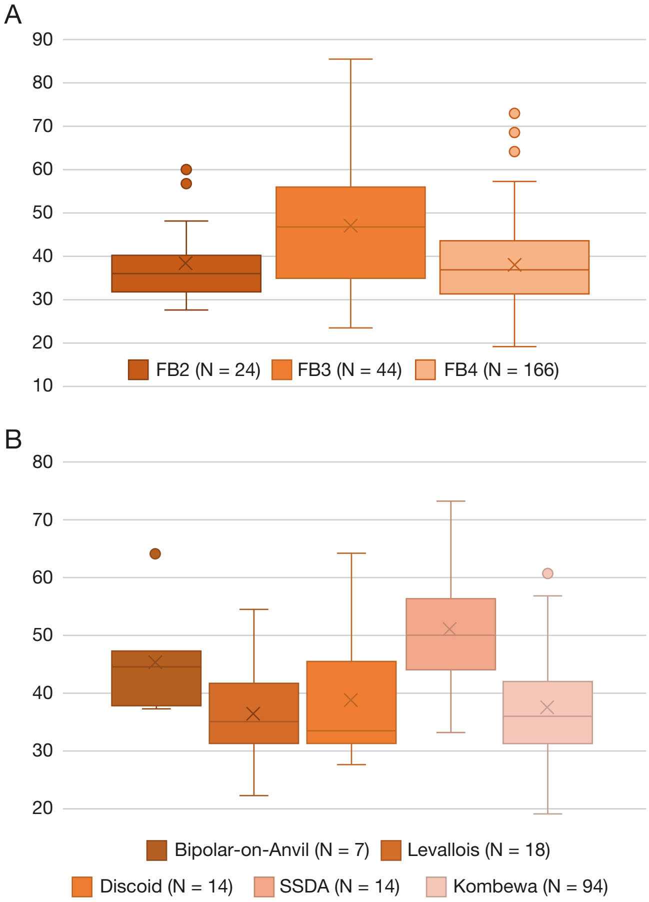

Fig. 7. — Discarded quartz cores: length (mm) per occupation phase (**A**) and debitage method (**B**).

with very wide flaking angles (the angle between the butt and the ventral surface), commonly >115º, with large and thick cortical or unfaceted butts (Forestier 1993), while, as Kobayashi (1975) and Mourre *et al.* (2011) have shown, the corresponding angles are ≤90° when the Bipolar-on-Anvil technique is used (Table 8).

Concerning the Bipolar-on-Anvil technique, it is important to note that it is not easy to identify, even though it produces very characteristic knapping stigmata (Fig. 8), namely: absence of a prominent bulb; presence of an opposite counter-bulb; occurrence of linear and rectangular striations; and predominantly cortical, punctiform, linear, or crushed butts. These attributes are relatively frequent in the Figueira Brava assemblage, supporting the notion that the Bipolar-on-Anvil technique was commonly used (Table 9).

Corroborating the mostly expedient nature of the exploitation sequences, cortical butts are 36.3% and unfaceted ones are 31.9%. Faceted (Fig. 9B, C, E) and dihedral butts are 3.7% and 8.6%, respectively (Table 10), and are mostly found on perimeter-edged flakes. The latter are non-cortical, oval, or circular blanks featuring a cutting edge extending across the entire periphery (except for the butt). They imply the use of more complex debitage methods, Levallois or Discoid (but secure attribution is often not possible, explaining why we classified/counted them by morphology rather than reduction

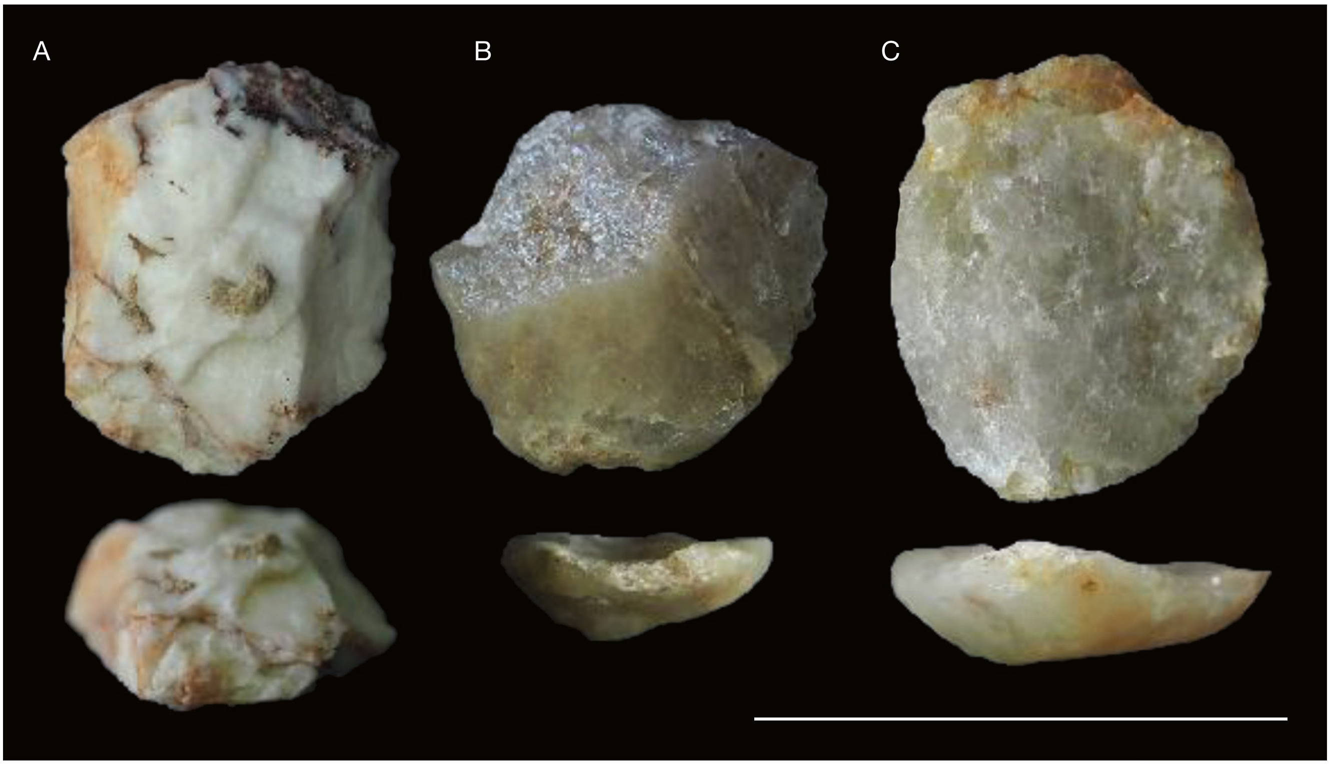

Fig. 8. — Typical stigmata of the Bipolar-on-Anvil technique in the Figueira Brava quartz assemblage: **A**, "cascade" step terminations of the scars; **B**, bluntness and cracks; **C**, punctiform butt. Scale bar: 5 cm.

Table 9. — Quartz debitage methods (based on debitage blanks, preparation material, and retouched tools).

Flaking method	FB2	FB3	FB4	Total	%
Discoid	1	1	14	16	16.0%
Levallois	2	7	17	26	27.0%
SSDA	2	1	16	19	20.0%
Kombewa	–	1	1	2	2.0%
Bipolar-on-Anvil	2	6	26	34	35.0%
Total	7	16	74	97	100%
Undetermined	53	54	370	477	–
Total	60	70	444	574	–

Table 10. — Quartz flakes' platform types.

Platform type	FB2	FB3	FB4	Total	%
Cortical	16	17	165	198	36.3%
Neocortical	1	–	11	12	2.2%
Unfaceted	28	23	123	174	31.9%
Dihedral	4	8	35	47	8.6%
Faceted	1	4	15	20	3.7%
Linear	3	3	16	22	4.0%
Punctiform	1	8	28	37	6.8%
Suppressed	–	–	1	1	0.2%
Broken	3	4	28	35	6.4%
Total	57	67	422	546	100%
Undetermined	3	3	22	28	–
Total	60	70	444	574	–

method). This inference is corroborated by two other observations: centripetal and, to a lesser extent, orthogonal, and chordal scar patterns are common in these types of flakes, and most flaking angles fall in the 90-110º range. Accepting the inference, 27% and 16% of our sample's quartz blanks were obtained via pre-determined reduction methods such as Levallois and Discoid, respectively (Table 9).

Knowing that the same blank types can be produced by different debitage methods, distinguishing Discoid from Centripetal Levallois flakes can be challenging – particularly when both occur in the same assemblage (Boëda 1993, 1994). González-Molina *et al.* (2020) have noted that two criteria are especially useful for differentiation: the flake's proportions, and the angle formed between the platform and the ventral surface. As flake proportions were not calculated in this study, platform angle served as the primary criterion for distinguishing Levallois from Discoid products. Levallois flakes generally present slightly obtuse angles, between 90° and 95°, sometimes wider, whereas Discoid flakes tend to display more obtuse angles, exceeding 100° (González-Molina *et al.* 2020). Flake thickness offers an additional criterion for differentiation, as Levallois products are generally thinner (Boëda 1993, 1994).

The assemblage contains 29 perimeter-edged, non-cortical flakes with prepared platform angles in the 90-119° range. This distribution corroborates the inference that they were extracted using Levallois or Discoid reduction strategies (note that Levallois flakes tend to be longer than they are wider, while Discoid flakes tend to be wider than they are longer; Fig. 10A, B). Consistent with their standing for the use of

Fig. 9. — Quartz flakes: **A**, Bipolar-on-Anvil flake from FB4; **B**, Levallois flake with faceted butt from FB3; **C**, Levallois flake with faceted butt from FB4; **D**, Levallois flake with unfaceted butt from FB4; **E**, pseudo-Levallois point with faceted butt from FB4; **F**, regular flake with cortical butt from FB3; **G**, unipolar SSDA flake from FB4. Scale bar: 5 cm.

those reduction methods, perimeter-edged, non-cortical flakes with faceted or dihedral butts and angles below 100° (Fig. 9B, C) have a mean thickness of 8.8 mm, whereas those with wider angles average 9.4 mm.

In FB4, the Discoid method is also plausibly responsible for most short-backed flakes and pseudo-Levallois points (Fig. 9E), characterized by rectilinear profiles, faceted or dihedral butts, centripetal or orthogonal scar patterns, and

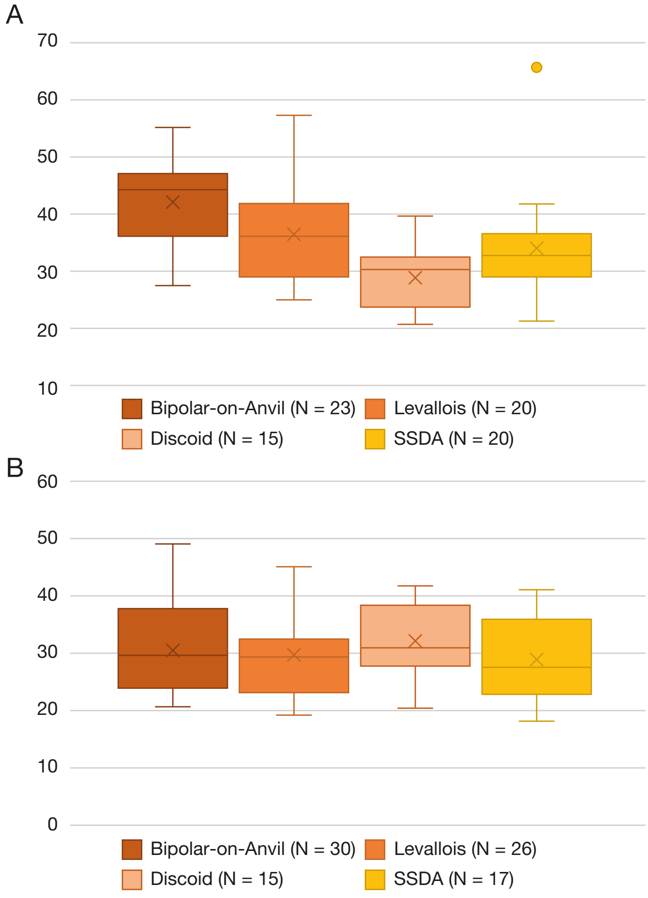

FIG. 10. — Quartz flakes: length (**A**) and width (**B**) according to the reduction scheme applied (mm).

TABLE 11. — Quartz retouched tool types (per occupation phase and excluding one tool of uncertain stratigraphic provenience).

Retouched tool types	FB2	FB3	FB4	Total	%
Notch	1	3	24	28	24.3%
Denticulate	2	2	39	43	37.4%
Double denticulate	–	–	1	1	0.9%
Bec	–	–	1	1	0.9%
Tayac point	–	–	2	2	1.7%
Lateral scraper	1	4	13	18	15.7%
Transversal scraper	1	–	3	4	3.5%
Oblique transversal scraper	–	1	1	2	1.7%
Convergent scraper	–	–	2	2	1.7%
Endscraper	–	–	1	1	0.9%
Partially retouched flake	1	2	6	9	7.8%
Retouched piece fragment	1	–	3	4	3.5%
Total	7	12	96	115	100%

platform angles almost always exceeding 100°. In FB2, the two backed flakes identified are linked to the reconfiguration of the debitage surface in a preferential scheme. In FB3, the Discoid method is possibly represented by a single flake with bipolar removals. As with cores, Levallois blanks are more frequent in FB3, while the Discoid method, poorly represented overall, is most frequently found in FB4 (Table 9).

The Bipolar-on-Anvil technique resulted in a more varied range of products: cortical flakes, semi-cortical flakes, bipolar flakes, naturally backed, and short or long cortically backed flakes (Fig. 9A). They tend to be longer (Fig. 10) and to present cortical remnants, usually occupying between 5 and 50% of the dorsal surface.

Retouched tools

The sample studied contains a total of 126 retouched tools, 116 of which are quartz (Table 1). They are small, with average lengths of *c.* 30 mm. For quartz, the predominant tool types are denticulates, followed by notches and sidescrapers (Table 11; Fig. 11A, C). FB4 is typologically more diverse, which, as with the other techno-economic categories, is most likely a function of the larger sample size.

Most retouched tool blanks are flakes bearing little or no cortex (which, when present, is usually distal), and a significant percentage are made on perimeter-edged, non-cortical flakes. Cortex is slightly more common in the blanks from FB4, which is likely related to this phase's somewhat more frequent usage of the Bipolar-on-Anvil technique (Table 9). FB4 also yielded three tools on other types of blanks: a scraper on a small, flat pebble (Fig. 11F); a denticulate obtained by alternating retouch applied to a patinated/rounded flake (Fig. 11D); and another denticulate retouched on the flat surface of a cleaved fragment. There are also two pieces on chunks: a denticulate and a piece with irregular retouch.

Almost half of the retouched tools are broken. When the diagnosis is possible, the retouch usually modifies the dorsal faces on their right or distal edges. Among denticulates, micro-notching is the predominant mode of retouch. Among scrapers, retouch is mostly scaled (Fig. 11B, D), featuring wide, short scars closely resembling fish scales (Inizan *et al.* 1999). In the case of partially retouched flakes, the modification of the edge is irregular and marginal (Fig. 11E).

Hammerstones

Cobbles used as hammerstones account for only 1.1% of the lithic assemblage and are attested exclusively in FB4 (Table 1). Although frequently broken, their original size can be reconstructed as >5 cm. Regarding raw material subtypes, J9.4a is the most common (N = 3), followed by J9.2 (N = 2) and J9.1 (N = 2).

The low number of hammerstones can be explained by the fact that some were later reused as cores, among which a small percentage bear diagnostic stigmata. This reuse did not result from raw material scarcity, but rather from the fact that, once broken, a hammerstone could provide a suitable platform for further flake extraction. This recycling behavior is most often observed in centripetal cores and one-or-two-extraction cores, which also happen to be the most common core types. When the breakage was particularly clean, the resulting platform would also have been especially well suited for centripetal removals.

Reduction

Most of the time, quartz cores were exploited in an expedient and "opportunistic" manner to produce regular flakes with <50% cortex and backed flakes (Binford 1979; Arzarello 2003;

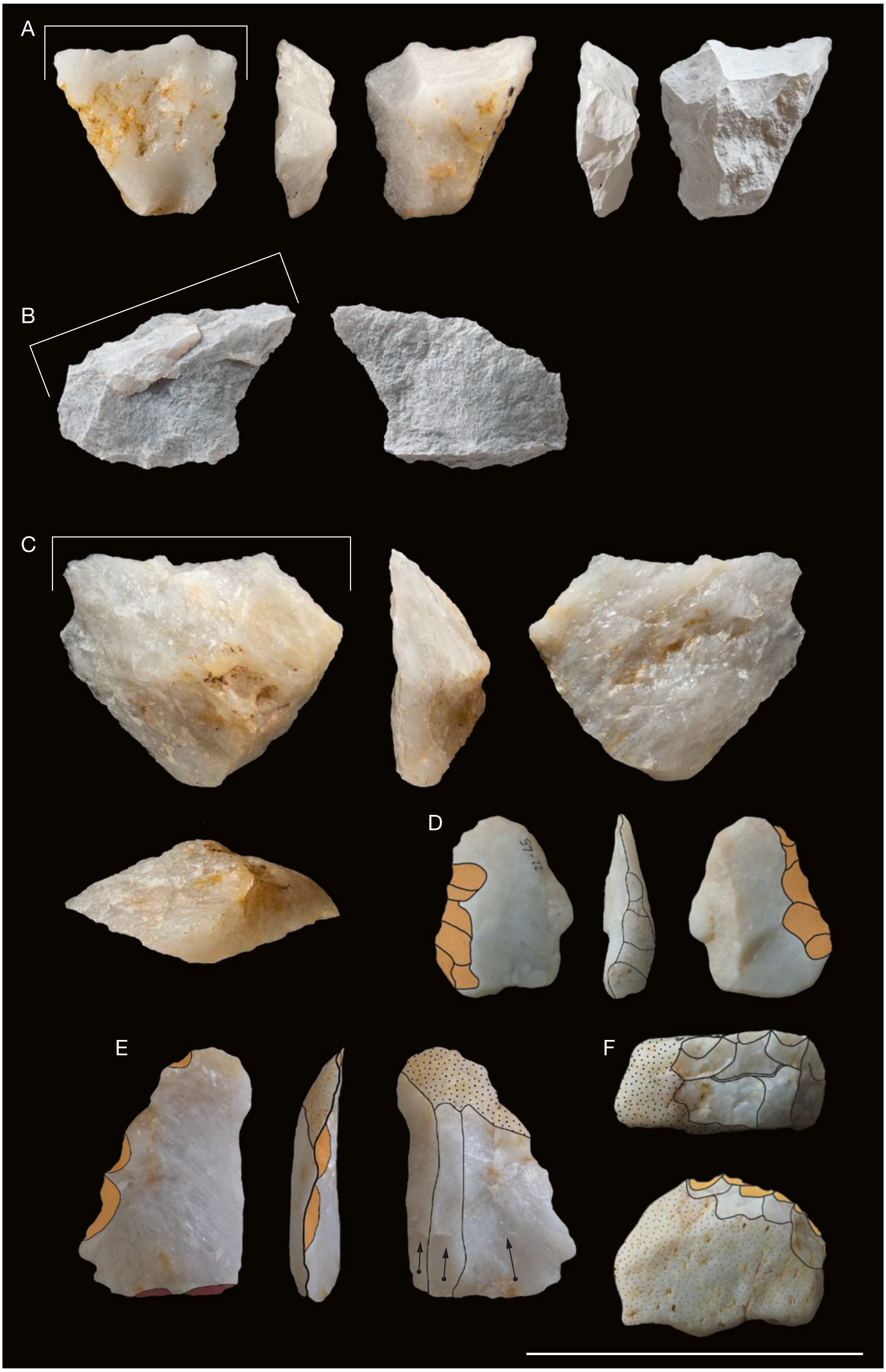

FIG. 11. — Quartz tools: **A**, denticulate from FB4 (with magnesium treatment on the right); **B**, transversal oblique scraper from FB3 with magnesium treatment; **C**, transversal scraper from FB4; **D**, denticulate on patinated/rounded flake from FB4; **E**, denticulate from FB4; **F**, scraper on flat pebble from FB4 phase. Scale bar: 5 cm. Credits: A-C, photos by José Paulo Ruas. The modified edge is indicated.

Table 12. — Quartz subtypes used by different debitage methods and techniques.

	Bipolar-on-Anvil	Discoid	Levallois	SSDA	Kombewa	Total
J9.1	1	6	10	4	39	60
J9.2	–	1	–	1	5	7
J9.3	–	–	–	1	1	2
J9.4a	–	–	–	–	2	2
J9.4b	–	–	–	–	1	1
J9.4c	–	–	–	–	1	1
J9.5	–	3	1	2	15	21
J9.6a	–	–	–	2	1	3
J9.6b	1	–	–	–	2	3
J9.6c	3	–	1	2	8	14
J9.7a	–	1	–	–	4	5
J9.7b	–	–	–	–	4	4
J9.7c	2	–	5	3	10	20
J9.7d	–	4	3	–	11	18
Total	7	15	20	15	104	161

Vaquero & Romagnoli 2017; Carpentieri & Arzarello 2022). Bringing together the results of the analysis of cores, blanks, and tools, the following can be concluded:

– despite FB3's somewhat higher representation of the Levallois concept, there are no substantial differences between the three phases of human occupation;

– throughout, the Bipolar-on-Anvil method was used, application of the Discoid method was rare, and raw material subtypes J9.1, J9.7c, and J9.7d were preferentially selected for the application of the more complex Levallois and Discoid methods (Table 12), of which the Kombewa cores may represent but an initial stage;

– at discard, Bipolar-on-Anvil cores are larger (Fig. 7B), so it is possible that, among other applications, this technique was used to open quartz pebbles and cobbles to produce blanks that could be used in more controlled, unipolar or centripetal reduction sequences;

– there is no correlation between the weight or length of the core and the size of the last removal (Fig. 12), which is consistent with targeting the production of small blanks, no more than *c.* 3 cm-long on average (perhaps as a deliberate strategy to compensate for the raw material's structural weaknesses). It is often noted that the Bipolar-on-Anvil technique is particularly effective for working hard, flawed rocks that are otherwise difficult to reduce to small sizes – such as certain varieties of vein quartz (Hiscock 2015). Future studies focusing on small-flake production may offer valuable insights into the full extent that this technique was put to use at Figueira Brava.

Economy

Through the Figueira Brava sequence, quartz is the most used raw material (Table 1). Figure 13 schematizes this raw material's exploitation economy. All steps of the *chaîne opératoire* are represented. On-site, reduction of raw pebbles is demonstrated by the number of cortical flakes. Anvil splitting was frequently employed to initiate volume reduction. The ventral surfaces of the resulting flakes were then exploited either with the same technique or through a variety of other methods. A significant proportion of the selected blanks underwent ramification (Bourguignon *et al.* 2004; Mathias *et al.* 2021), with Kombewa cores potentially representing the initial stage of Levallois reduction sequences. The primary objective appears to have been the production of small flakes, <3 cm, whose shape is closely linked to the debitage method applied (Fig. 10). When retouched, blanks were transformed into notches, denticulates, and scrapers.

Flint was exploited differently (Zilhão *et al.* 2020). FB2 yielded no cores and only a few <50%-cortical or non-cortical flakes. FB3 yielded a single core, and a few cortical flakes. FB4 accounts for most of the flint artefacts and yielded eight cores (including fragments), mostly reduced by Kombewa or Levallois methods and largely exhausted. The flake assemblage includes large, preferential Levallois blanks that could not have been extracted from the much smaller cores discarded at the site and must represent imported items. This conclusion is further supported by the fact that, among the totality of the flint assemblage, 64% of the retouched tools are made on cortical or partly cortical blanks. This indicates that they were imported as finished implements or as blanks that, prior to discard, were used or re-sharpened at the site (as shown also by a couple of retouch flakes). In the sample studied here, the few tools are denticulates and sidescrapers.

Quartzite cores are present throughout but, unlike flint ones, they are far from exhausted. The blanks are mostly cortical or partly cortical (61%). Tools are rare and represented by denticulates and notches made on partly cortical blanks.

As far as tool manufacture is concerned, a similar approach was followed, regardless of raw material. The same types of blanks – flakes with <50% of cortex or non-cortical ones – were selected, and the same kinds of edge modifications were applied.

DISCUSSION AND CONCLUSIONS

Quartz, a raw material with more internal flaws and more prone to fracture unpredictably, has been widely understood as unsuitable for the application of elaborate knapping techniques. The idea that the technical constraints of the Levallois concept necessitate quality raw materials, in contrast to Discoid or other techniques, derives from a wide range of Middle Paleolithic sites of Southern France (Mathias *et al.* 2020). However, recent work has called into question this proposition, as Levallois productions using quartz and quartzite have been documented at several Middle Paleolithic sites in the Pyrenees and the Iberian Peninsula (e.g. Eixea *et al.* 2016; Deschamps 2019; Ramos *et al.* 2024).

The role of quartz in the Middle Paleolithic of Iberia

Multiple sites of the Middle Paleolithic of Iberia, where non-flint raw-materials, such quartz and quartzite, are more common than flint (Pereira & Benedetti 2013), have challenged the above dichotomy (although a few exceptions exist, like the Abric Romaní, where flint from far away was consistently

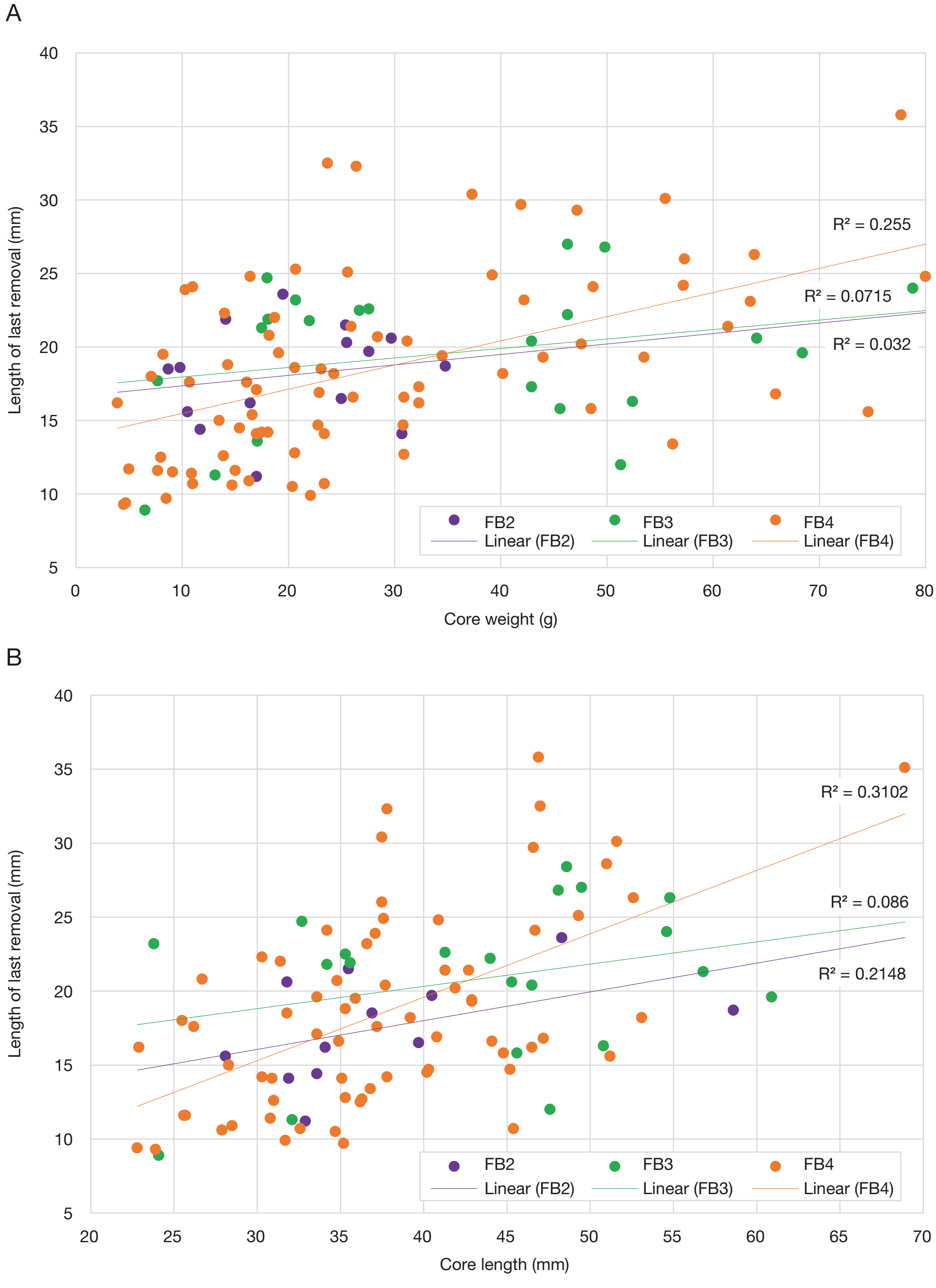

Fig. 12. — Last flake removals as a function of core weight (**A**; excluding five outliers from phases FB3 and FB4 weighing >100 g) and core length (**B**).

preferred over locally availably quartz and quartzite; Vaquero 1999) (Table 13). The long-standing belief that the use of harder raw materials inevitably requires technological approaches distinct from those used for flint has been challenged by Marks *et al.* (2001), Mourre & Thiébaut (2008), Eixea *et al.* (2016), Deschamps (2019), and Deschamps & Zilhão (2018). In the case of the Gruta da Oliveira site in Torres Novas, Portugal, Deschamps & Zilhão (2018) demonstrated that, in the stratigraphic units analyzed, the reduction methods employed were the same for quartzite and flint. A similar pattern is observed at Abrigo de la Quebrada (Eixea *et al.* 2016), where flint is locally abundant and Levallois reduction sequences are represented among quartzite and limestone too. Likewise, at Gruta Nova da Columbeira in Bombarral, Portugal, where quartz is the predominant raw material, followed by quartzite and flint in similar proportions, the reduction methods applied show no substantial differences between raw material types (Cardoso *et al.* 2002).

Table 13. — Frequency of quartz in the Iberian Middle Paleolithic sites mentioned in the text. *, Counts are for levels 8-9 only; **, quartz is the majority.

Site	Location	Site	Age	%	Levallois	Discoid	References
Oliveira	Portugal	Cave	MIS 5a	10%*	?	?	Marks *et al.* 2001; Zilhão *et al.* 2020
Columbeira	Portugal	Cave	MIS 5-2	37%**	yes	yes	Cardoso *et al.* 2002
Azinhal	Portugal	Open-air	MIS 4-3	*c.* 50%	residual	yes	Almeida 2012
Santa Cita	Portugal	Open-air	MIS 3	58%	no	no	Cura *et al.* 2017
l'Arbreda	Spain	Cave	MIS 3	73%	no	no	Bracco 1997
Avellaners	Spain	Open-air	?	77%	yes	no	Mora 1984
Navalmaíllo	Spain	Shelter	MIS 5-4	78%	residual	yes	Márquez *et al.* 2013
Buena Pinta	Spain	Cave	MIS 4-3	*c.* 80%	no	no	Mielgo *et al.* 2024
Cueva del Camino	Spain	Cave	MIS 5-4	*c.* 80%	?	?	Arsuaga *et al.* 2012
Figueira Brava	Portugal	Cave	MIS 5	83%	yes	yes	Melo 2023; this study
Cova Eirós	Spain	Cave	MIS 5	88%	yes	no	Lazuén *et al.* 2011
Cardina/ Salto-Boi	Portugal	Open-air	MIS 6-3	90%	yes	yes	Ramos *et al.* 2024
Diable Coix	Spain	Open-air	?	91%	yes	no	Mora 1984
Escoural	Portugal	Cave	MIS3-2	99%	yes	?	Cardoso 2006
Lagoa Funda 2	Portugal	Open-air	?	100%	yes	yes	Bicho 2004
Vale da Fonte	Portugal	Open-air	?	100%	?	?	Bicho 2004

Many other sites illustrate the use of the Levallois concept on quartzite, but little is known regarding Iberian Middle Paleolithic sites where quartz is the most used raw material (Table 13). Bracco (1997) notes that, at the site of l'Arbreda, in Catalonia, the debitage methods employed for quartz were distinct, even though the blanks selected for tool manufacture were no different from flint ones. Likewise, at Santa Cita in Tomar, Portugal (Cura *et al.* 2017), no evidence was found that predetermined knapping methods were applied. At Azinhal, located in Vila Velha do Ródão, Portugal, the Discoid method predominates, with Levallois represented by only a few flakes (Almeida 2012). At Cardina-Salto do Boi, in Vila Nova de Foz Côa, Portugal, both Levallois and Discoid methods were applied, especially so in the assemblage from the GFU6-7 stratigraphic unit (Ramos *et al.* 2024). At Cova Eirós, Lugo, Spain, the Levallois method is employed more frequently than the Discoid method, the latter having been used for quartzite only (Lazuén *et al.* 2011; Rodriguez-Alvarez *et al.* 2011). At the Navalmaíllo rockshelter, in Pinilla del Valle, Spain, where the incidence of the Levallois method is low, application was not observed on chert-like rocks and would seem to have been restricted to quartz and quartzite (Márquez *et al.* 2013).

This body of evidence confirms that there is no necessary relationship between the Levallois concept and any specific raw material. While local availability is known to have played an important role in the Middle Paleolithic (Geneste 1991), in sites where multiple raw materials are present the use of quartz is not necessarily a simple byproduct of immediate abundance. The use of non-flint raw materials in Levallois productions can be related to length of occupation and the activities carried out at the site (Eixea *et al.* 2016). Further studies are needed to determine whether regional patterns exist in quartz exploitation in Iberia and whether its management varied according to site function.

Figueira Brava's contribution

Figueira Brava adds to and considerably expands current knowledge about the use of quartz in the Middle Paleolithic of Iberia. Based on our analyses, the following evidence-based statements can be made regarding quartz exploitation at Figueira Brava:

– quartz was abundantly and consistently used throughout the site's human occupation, despite the nearby availability of other raw materials. This observation suggests that the use of quartz might have been dictated by choice, not opportunity. Experimental (e.g. Mourre *et al.* 2011; de la Peña 2015; Pargeter & de la Peña 2017; Spry *et al.* 2021) and techno-economic studies (Tallavaara *et al.* 2010; de Lombera-Hermida & Rodríguez-Rellán 2016; Knutsson *et al.* 2016; Manninen 2016; Márquez *et al.* 2016) have shown that quartz can play diverse roles in prehistoric technologies depending on its status and abundance, challenging the view of quartz as a mere substitute. As Eixea *et al.* (2016: 48) pointed out, particular raw materials with appropriate characteristics may have been preferred for the manufacturing of certain kinds of implements. Further work – including targeted surveys and use-wear analysis – is needed to better characterize Figueira Brava's quartz lithic assemblages and the economic and functional objectives associated with the consumption of this raw material;

– our study confirms that the petrographic and mechanical properties of quartz influenced reduction strategies. While most volumes were exploited expediently, more complex debitage methods, such as Levallois and Discoid, were occasionally applied to selected quartz types with finer, more granulated textures and fewer internal flaws;

– specific strategies appear to have been employed to mitigate quartz's tendency to fracture. Previous work (e.g. Tallavaara *et al.* 2010; Manninen 2016) has identified technological choices that can help in managing this limitation, such as: 1) producing artefacts with thicker butts to yield thicker products less prone to breakage; 2) producing smaller blanks, especially if intent on subsequent modification into retouched tools (Hiscock 2015; Knutsson *et al.* 2016); 3) preferentially using cortical or neocortical surfaces as striking platforms (de Lombera-Hermida & Rodríguez-Rellán 2016); 4) organizing reduction in longitudinal sequences (de Lombera-Hermida

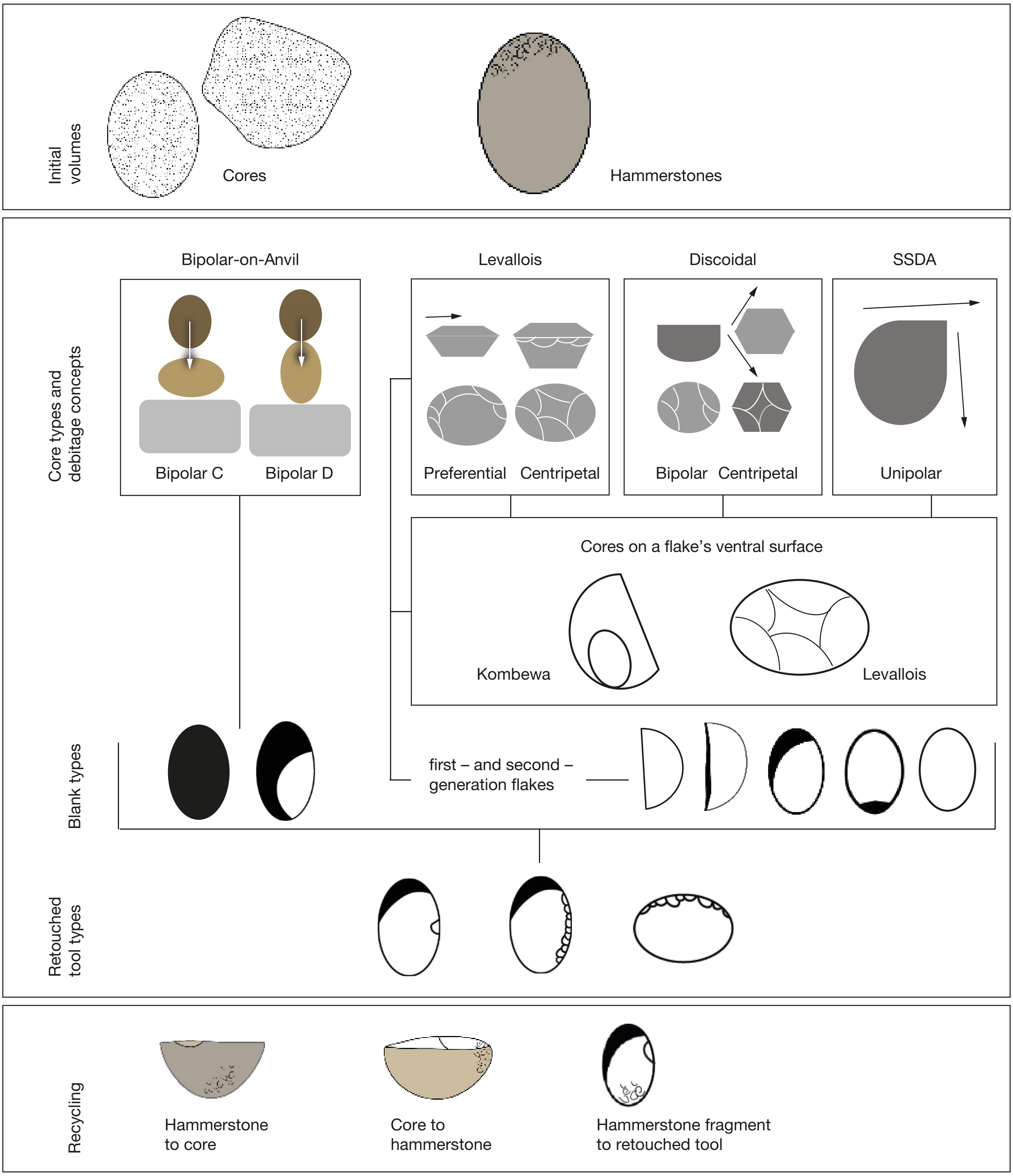

Fig. 13. — Figueira Brava quartz economics as illustrated by the phase FB4 assemblage. The **black-shaded areas** indicate cortex cover.

et al. 2011, 2016); and 5) employing the Bipolar-on-Anvil technique. The assemblage from Figueira Brava is consistent with application of these strategies;

– the methods used to knap quartz blocks remained largely consistent across the three human occupation phases. Given the small size of the study area relative to the original area of occupation, minor variations, such as the somewhat higher frequency of Levallois in FB3, are parsimoniously explained by sampling bias rather than change in technological preference.

Figueira Brava's unique setting – coastal location with abundant sources of food and raw material – enabled Neanderthal groups to maintain long-term usage of the site. Seasonality data indicate human presence in every season: aquatic and marine birds, along with mature pinecones, were exploited/collected during autumn and winter, while brown and spider crabs were gathered in the summer (Zilhão *et al.* 2020).

Quartz, abundantly available in the vicinity, was the raw material of choice for the making of the stone tools involved in the procurement, processing, and consumption of these resources. Although often considered a lower-quality raw material compared to flint in terms of knapping properties, quartz's local abundance and adequate performance characteristics (e.g. hardness and durable edges) must have made it entirely suitable for the activities carried out at the site.

A careful selection of more granular-textured varieties allowed for the application of more complex debitage methods. The reduction sequences employed combined different technological systems (Bourguignon *et al.* 2004), taking advantage of the natural convexities of collected blocks, and aimed at the production of small flakes. These strategies fully harnessed the potential of quartz, demonstrating technological flexibility and adaptation to available resources. As H. Knutsson (2014) aptly stated, "simple needs not mean archaic."

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