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A local history of bifacial shaping - Middle Pleistocene at Arago Cave (Pyrénées-Orientales, France)

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Mots clés : Biface; Fonction; Pléistocène moyen; Acheuléen; Comportement; *Homo heidelbergensis*.

Abstract:

The morpho-technical variability of bifaces is often put forward as an argument to define hominid traditions or cultural changes, especially during the Lower Palaeolithic and the Acheulean. However, the interpretation of this variability often comes up against the biases induced by the variability of the available raw materials. The multi-stratified site of Arago Cave offers a unique opportunity to observe the morpho-technical evolution of bifaces in an *a priori* constant mineral environment, between MIS 14 and MIS 12. We conducted a morphological and technological analysis of bifacial production from all stratigraphic units, in correlation with petrographic data and functional objectives. Due to the limited sample size, the notion of know-how could not be addressed here, but other data related to tool ergonomics and traditions are highlighted from a diachronic perspective. The results show that most of the morphological variations observed between the two main stratigraphic units of Arago Cave containing bifaces are related to different functional objectives, possibly due to different site functions in the two units. Although there are some fluctuations in size and production techniques between the two units, no technical discontinuity was observed. Shaping methods and raw materials are relatively consistent, reflecting similar knowledge of the mineral environment. Our study reinforces the idea that the biface is not a single tool but a production mode (bifacial shaping) encompassing several different tool types, as is the case for debitage.

Résumé long :

Malgré plusieurs tentatives pour ne plus considérer un seul type d'outils au Paléolithique inférieur, les bifaces constituent toujours le fondement des réflexions sur l'évolution comportementale et les migrations humaines au Pléistocène inférieur et moyen. Cet intérêt particulier peut s'expliquer car il s'agit des seuls outils pour lesquels les analystes pensent percevoir une norme et peuvent, de fait, envisager d'interpréter les variations de chaînes opératoires. Présents en Afrique et en Eurasie depuis 1.7 Ma, les bifaces permettent en effet de documenter une large fenêtre de l'histoire technique humaine. Mais cette amplitude spatio-temporelle, a pour revers une variabilité des contextes - notamment géologique, anthropologique et taphonomique - rendant le plus souvent caduques les tentatives de globalisation. Parallèlement, un retour épistémologique sur les bifaces, documente l'accrétion de paradigmes – en particulier leur perception comme monolithe fonctionnel – qui tendent à scléroser les discussions.

En effet, les bifaces sont le plus souvent associés à un seul type d'outil, un couteau à tout faire mais surtout destiné à des activités de boucherie. Pourtant, ce n'est pas le résultat des analyses fonctionnelles, malgré leur faiblesse numérique liée à la conservation médiocre des traces

d'usages. Ainsi, si l'association avec des activités de boucherie existe, les résultats issus de la revue bibliographique illustrent des usages en découpe, en raclage et en percussion lancée. Des bifaces sont également utilisés pour le travail du bois en raclage, pour la découpe de racines ou encore en percussion lancée dans le sol ou sur du bois. La diversité des gestes effectués et des matériaux travaillés – associée à la variabilité probable des systèmes socio-économiques dans lesquels les bifaces s'insèrent – conditionne la définition d'outils différents.

Devant l'impossibilité de donner du sens à la variabilité des bifaces à l'échelle globale, nous proposons d'étudier l'évolution des bifaces dans un contexte géographique similaire et sur un temps relativement court (à l'échelle de deux stades glaciaires successifs), permettant d'atténuer l'impact des facteurs environnementaux.

Ce cadre analytique est offert par le site de la Caune de l'Arago (Pyrénées-Orientales, France), disposant de plusieurs niveaux d'occupations contenant des bifaces datés du Pléistocène moyen. Site en grotte à l'extrémité sud de la France, la Caune de l'Arago s'ouvre à l'aplomb du Verdoube, au sein d'une vallée sous la forme d'une anse, propice aux activités cynégétiques. Le remplissage de la cavité est subdivisé en plusieurs complexes stratigraphiques, dans lesquels d'autres subdivisions permettent de raisonner à l'échelle d'unités archéo-stratigraphiques (UA). L'analyse porte ici sur les UA contenues dans les trois ensembles du complexe moyen, pour lesquels les données sédimentologiques, paléontologiques et radiométriques, permettent une corrélation avec les MIS 14, 13 et 12. Les bifaces sont présents dans les UA des ensembles I et III, corrélés respectivement aux phases glaciaires des stades 14 et 12. Le site offre donc la possibilité d'analyser localement l'évolution des bifaces, dans des conditions environnementales (climat et ressources lithologiques) a priori semblables. En excluant les pièces pour lesquelles l'état de conservation ne permet pas une attribution certaine à cette catégorie, la Caune de l'Arago livre 64 bifaces : 39 dans l'ensemble I et 25 dans l'ensemble III, dont 28 aptes à une analyse technico-fonctionnelle.

Partant du constat que la production de bifaces répond à des objectifs fonctionnels variés et que les analyses tracéologiques se heurtent à la reproductibilité des résultats en l'absence de récurrences liées à la conservation insuffisante des artefacts, la diversité fonctionnelle est abordée grâce à une analyse technico-fonctionnelle. Elle intervient en supplément des analyses pétrographiques et technologiques et permet de caractériser différents types d'outils au sein d'un même mode de production. L'outil, considéré en tant que système, est composé d'une unité active, d'une unité de préhension et d'une zone de transmission de l'énergie. L'association de l'unité active et préhensive crée un couple fonctionnel caractérisant la structuration de l'outil. L'unité active peut présenter différentes conformations qui, une fois individualisées, permettent de créer des techno-types. Ils correspondent au regroupement d'outils présentant potentiellement un même schème de fonctionnement.

Les résultats permettent de mettre en évidence treize techno-types différents, dominés par des couples fonctionnels (partie active et préhensive) structurés par une opposition transversale ou oblique. Les conformations dominantes de la partie active sont pointues et convexe en plan. Les techno-types sont diversement représentés à l'échelle des unités archéo-stratigraphiques et des ensembles stratigraphiques, montrant une variété des objectifs fonctionnel. Les matières premières sont pareillement diversifiées dans les deux ensembles, montrant une continuité dans les connaissances de l'environnement minéral. A l'exception de l'utilisation de la percussion tendre dans l'ensemble I, les méthodes et les techniques de production ne varient pas sensiblement en diachronie.

La mise en relation de l'évolution de ces objectifs fonctionnels avec les variations des paramètres environnementaux est inopérante. En effet, les ensembles I et III de la Caune de l'Arago s'insèrent dans des périodes glaciaires, avec un spectre faunique relativement similaire. Plus globalement, il semble que les temporalités de l'évolution climatique et de l'évolution technologique ne s'expriment pas dans les mêmes espace-temps, ne permettant pas de percevoir l'influence du premier sur le second, au moins pour le Pléistocène moyen. La présence d'une phase de réchauffement intercalée, correspondant à l'ensemble II de la Caune de l'Arago, permet d'observer l'absence de bifaces mais pas de leurs déchets de fabrication et donc d'envisager une relation entre la fonction du site et la diversité des objectifs de la production bifaciale. L'hypothèse d'un lien entre la durée d'occupation et les objectifs fonctionnels remplis par les bifaces peut être émise, mais ne peut être démontrée sur la base unique des données de la Caune de l'Arago.

Pour conclure, la diversité des objectifs fonctionnels perçus parmi les bifaces de l'Arago s'avère l'expression multiple d'un même mode de production qu'est le façonnage bifacial. L'idée d'un outil invariant et polyfonctionnel n'est pas soutenue par les séries de la Caune de l'Arago. La variabilité des résultats technologiques et fonctionnels en Afrique et en Eurasie, l'intégration – ou non – des ces outils dans des cycles d'existences longs ou encore la variété des choix pétrographiques, montre bien toute la diversité des outillages obtenus par façonnage bifacial. Il est donc temps d'analyser la variabilité fonctionnelle au sein de ce système productif et de la confronter ensuite aux choix de matières premières et aux savoir-faire afin de discuter l'évolution cognitive et comportementale humaine au cours du Paléolithique inférieur.

Introduction: Bifacial tool variability

The first description of bifaces by G. De Mortillet (1872) highlights shape variability. Despite this underlying variability, De Mortillet only created a single type of biface, as in his view, all bifaces have an « *air de famille* » (a family resemblance) (Mortillet, 1875 *in*. Nicoud, 2011). This apparent similarity is induced by the production technique of these tools: namely bifacial shaping, which constituted the crux of the definition of bifaces by A. Vayson de Pradenne (1920) in the first part of the twentieth century. During the first half of the last century, the morphological variability of handaxes was considered as a marker of chronological evolution (rough and thick handaxes were considered to be the oldest, while well-worked implements were thought to be more recent), or of cultural traditions (*e.g.* Bordes, 1961 ; Roe, 1969).

Over the past forty years, the development of technological and multidisciplinary analyses has tended to emphasize biases in the study of biface shape variability. Most of the time, the defining elements were considered to be: raw material diversity including lithology and blank type (nodule, pebble, slab) (Villa, 1981 ; Turq, 1992 ; Ashton and McNabb, 1994 ; White, 1995 ; 1998 ; Ashton and White, 2003); the type of site, in terms of habitat type (cave or open-air site) or site function (workshop site, killing site, life site, or a combination) (for a review see Moncel *et al.*, 2015, p. 306), or reduction processes (McPherron, 2000 and 2006). Surprisingly biface function has rarely been considered to be a factor of morphological variation, although it forms the base of the *chaîne opératoire* (Lepot, 1993). This appears to be linked to two paradigms regarding biface function: the biface can be considered as a multipurpose tool or a butchery tool (*e.g.*, Turq, 2001 ; Moncel *et al.*, 2015). These assumptions imply that if tool function is invariant, it cannot be a factor of morphological variability.

However, functional results from use-wear analysis tend to depict a somewhat different picture, with a high diversity of functions. Many studies conclude that bifaces were used during butchery processes, but it is important to note that the movement of bifaces is not the same for cutting actions (Keeley, 1980 ; Gysel and Cahen, 1981 ; Ollé, 2003 ; Garcia-Medrano, 2014), disarticulation (Keeley, 1980) or scraping (Soladenko *et al.*, 2015). The definition of tools usually depends on the movement and the worked material (Sigaut, 1991). Therefore, in the case of butchery processes, the bifaces used correspond in actual fact to different tools. Other use-wear results indicate that bifaces were used for cutting roots (Beyries *in* Lhomme *et al.* 1998), sawing (Binneman and Beaumont, 1992), perforating wood (Keeley, 1980), for chopping actions on soil (Rots and Van Peer, 2006) or on hard or semi-hard materials (Mitchell, 1998 ; Wenban-Smith and Bridgeland, 2001 ; Viallet, 2016a).

These results show that bifaces are not only butchery tools, and do not demonstrate the use of one piece for several different tasks. In actual fact, the term “biface” appears to encompass different tool types, and corresponds rather to a production mode comprising several tools. Thus, in the same way as for contemporary tools, function can be an important factor of morphological variation within the biface group. Recent studies have shown that function can be a major factor in biface shape variation during the Middle Pleistocene from Europe (Soriano, 2000 ; Boëda, 2001 ; Nicoud, 2011 ; Viallet, 2016a and b), Africa and the Middle East (Albrecht and Müller-Beck, 1988 ; Boëda *et al.*, 2004 ; Chevrier, 2012), and Asia (Bodin, 2011).

In this paper, we aim to investigate the evolution of functional diversity and morphological variability of the bifaces from a key Acheulean site from Southern France: Arago Cave. This deposit contains 16 levels of human occupation with bifaces, between MIS 14 and 12 (Falguères *et al.*, 2015). The chronological order of the various occupation levels in the Middle Complex has recently been debated (Lebreton and Lopez-Garcia, 2023 ; Nicoud *et al.*, 2022). The multi-stratified site provides the opportunity to circumvent questions linked to raw material constraints and to compare lithic assemblages in an *a priori* relatively similar environment (Lebreton, 2018 ; Hanquet, 2011 ; Lumley *et al.*, 2015). The results provide an outline of variations in bifacial shaping, use and evolution during the first half of the Middle Pleistocene.

Material: Arago Cave, a key site for the study of biface shape variability

Arago Cave (« Caune de l’Arago », Pyrénées-Orientales, France) is a multi-stratified site in the South of France, comprising several Middle Pleistocene lithic complexes (Lumley (Ed.), 2015) (fig. 1). Among these, three stratigraphical units are correlated with MIS 14, 13 and 12 – from bottom to top (Falguères *et al.*, 2015 ; Lumley (Ed.), 2015). Unit 1 (MIS 14) and Unit 3 (MIS 12) contain different archaeostratigraphical units (referred to as AU), attributed to the Acheulean techno-complex. Unit 2 (MIS 13) contains AU with human occupations and lithic remains but without bifaces, or Large Cutting Tools (LCT). However, some bifacial production waste would be present (Capellari *et al.*, 2021). These different AU contain abundant faunal remains, which provide information on human behaviour related to carcass acquisition and processing (Moigne, 1983 ; Rivals, 2002 ; Lumley *et al.*, 2004 ; Lebreton, 2018).

Unit 1 is subdivided into 7 AU, named Q4, Q3, Q2, Q1 and P3, P2 and P1. The excavation of unit Q is still in progress. The first data from palynological analysis show cold and dry

environments (Lumley *et al.*, 2015), reinforcing palaeontological (Moigne *et al.*, 2006) and micro-palaeontological data (Hanquet, 2011 ; Lebreton, 2018). The AU P1 is related to *Ursidae* occupation, and does not present lithic remains. The AU Q4, currently excavated over a surface of 15 m², has not yet yielded bifaces or LCT.

Unit 3 is subdivided into 12 AU, named G4, G3, G2, G1, Fi, F3, F2, F1, E4, E3, E2 and E1, from bottom to top. Sedimentological and palaeontological analyses (Perrenoud, 1993 ; Moigne *et al.*, 2006, respectively) indicate cold climates with strong winds. Micro-palaeontological analysis from micro-mammals and herpetofauna (Lebreton, 2018 ; Manzano, 2015) and palynological data (Lartigot, 2007) show a more contrasted environment with continental and Mediterranean influences.

Whitin this level, Arago Cave has yielded 5 AU attributed to the Acheulean techno-complex, attributed to MIS 14, and 11 AU attributed to the Acheulean techno-complex, dated to MIS 12. Environmental conditions appear to be relatively consistent between the different AU, with low temperatures in open landscapes comprising small-forested areas and steep slopes. Some differences in raw material frequencies were observed, but these same types were used throughout the stratigraphy, showing that raw material accessibility did not change. As a result, raw material selection for tool production reflects a deliberate choice and not a constraint. Thus, we can study the technical evolution of bifaces at Arago Cave without the bias induced by raw material availability.

Some authors consider a larger number of bifaces (Lumley (Ed.), 2015). We do not agree with this typological attribution: the artefacts are too altered and only a vaguely amygdaloid form seems to justify inclusion in the biface group (Lumley (Ed.), 2015). These tools were therefore not included in our analysis (fig. 2). In total, Arago Cave has yielded 64 bifaces. Due to weathering, fourteen of these artefacts could not be technologically analysed, but were nonetheless relatively confidently classified as bifaces.

Unit 1 contains the majority of bifaces (n = 39), which are distributed in AU Q3, Q2, Q1, P3 and P2 (fig. 3). Unit 3 includes 25 pieces in levels G3, G2, G1, Fi, F3, F2, F1, E4, E3, E2, E1 (fig. 4). Level RFB corresponds to the later filling of a fissure, and the biface it contains is therefore not chronologically comparable to those from Units 1 and 3 and is thus excluded from the analysis. Since the determination of the AU of Arago Cave, published in 2015 (Lumley *et al.*, 2015), AU D does not contain bifaces, in contradiction with a recent publication (Barsky *et al.*, 2019) based on earlier data (Barsky, 2000).

Method: Metrical and Technical-functional analysis

Morphological and technological variability is quantified using different observations, measurements and indices. Each element is analysed to reconstruct the *chaîne opératoire*, including raw material identification and blank type (pebble, flake, etc.), the type of hammer used, and the shaping method (shaping and finishing) (Boëda, 2013 ; Inizan *et al.*, 1995 ; Pellegrin, 1990 ; Soressi and Geneste, 2011). Based on the chronology of the identified gestures, a distinction is made between a facial and a lateral shaping process (Moncel, 1995). Thus, in addition to the length, width and thickness of each piece, measurements are also taken of as the distance between the tip and the maximum width.

In order to assess the impact of functional variability on morphological variability, we required a methodology to characterise functional groups. Microwear analyses can provide results for the Lower Palaeolithic series (*e.g.*, Keeley, 1980 ; Mitchell, 1998 ; Ollé, 2003 ; Wenban-Smith and Bridgeland, 2001), but such results are still rare and only concern a small quantity of pieces (Guibert-Cardin, 2022 ; Viallet, 2016b). Therefore, they cannot be extrapolated to the whole bifacial shaping technical mode. This is why we use the so-called "technical-functional" analysis (Boëda, 2021). Based on the morphology of edges and surfaces and the way they are shaped, it allows tools to be grouped together. The assumption is that these technological and morphological characteristics lead to similar functional potential (Albrecht and Müller-Beck, 1988 ; Soriano, 2000 ; Boëda *et al.*, 2004 ; Bodin, 2011 ; Nicoud, 2011 ; Chevrier, 2012 ; Viallet, 2016b).

The aim here is to carry out a detailed analysis of the *chaînes opératoires* in order to determine and isolate specific processing phases. The morphological consequences of these shaping phases are considered as autonomous units, called technico-functional units (TFU). They can present morphological differences (sharpening angle, profile delineation, etc.) and can thus be transformative (cutting edge), or prehensive (gripping edge). The cutting edge is defined by a regular cross section and an angle inferior to 90° (Soriano, 2000) The combination of a Transformative contact TFU (TFU T) and a Prehensive contact TFU (TFU P) creates the structure of the tool and imposes a restricted range of gestures for the activation of the TFU T (Boëda, 1997 ; Bourguignon, 1997 ; Viallet, 2016b). Furthermore, the specific conformation of the TFU T affects the functional efficiency of the tool for a given function.

Based on ethnographic data (Gould *et al.*, 1971 ; Hayden, 1977 ; Schick and Toth, 1993), observations of contemporary tooling (McGorry *et al.*, 2003, 2005 ; Atkins, 2009 ; Key, 2016 ; Singh *et al.*, 2016) and edge effectiveness experiments (Key and Lycett, 2015, 2017), edges with an angle of less than 90° are more likely to be active edges than those with an angle greater than 90°. The latter are more likely to be gripping areas. Similarly, cutting edges with an angle of less than 45° and a straight edge are more effective for inward cutting actions. Conversely, cutting edges with an angle greater than 45° are more effective for outward cutting with cast percussion or inward cutting with thrusting percussion. For this latter gesture, the tool must be heavy for a manual grip.

It is thus possible to define tool groups based firstly on their specific structure (TFU T and TFU P pair), and secondly on their specific TFU T conformation (Albrecht and Müller-Beck, 1988 ; Soriano, 2000 ; Boëda *et al.*, 2004 ; Bodin, 2011 ; Chevrier, 2012 ; Viallet, 2016b).

In this way, we propose to assess synchronic and then diachronic variability in order to perceive the influence of techno-cultural factors.

Results: Variability of functional goals

For technical-functional and metrical analyses, only whole artefacts are taken into consideration. At Arago Cave, particularly in Unit 1, some bifaces are part of long cycles with phases of resharpening or recycling, sometimes causing breakage (Viallet *et al.*, 2022). Biface fragments are thus frequent (n=21) and were excluded from our analysis: it is not possible to

carry out a technical-functional analysis on broken tools. In total, 15 bifaces in Unit 1 and 13 in Unit 3 were analysed for this paper.

The identification of the position of the active part (TFUT) of the biface and its position in relation to the prehensile part, combined with the conformation of the cutting edge, are used to define two different tool structures, with only one cutting area. Within these structures, based on the conformational variability of the TFU T, 13 types of tools can be distinguished, for 24 bifaces (tab. 1 and 2). Four bifaces comprise two or more TFU T, and will be described in a second stage.

Transverse opposition between TFU T and TFU P

Eight tool types correspond to this functional structure. TP1, TP2 and TP3 bear a pointed TFU T, extending over two-thirds of the tool circumference. When the cutting angle is greater than 45°, it is associated with a biconvex (TP1) or plano-convex (TP2) cutting edge morphology in cross-section. If it is less than 45°, the cutting edge is bi-planar with an asymmetrical cross-section (TP3) (fig. 5).

For TP4, TP5 and TP6, the TFU T is pointed in plan, and extends over one-third of the tool circumference. For TP4, the cutting edge angle is greater than 45° with a trihedral cross-section. For TP5, the angle is also greater than 45°, but with a biconvex cross-section. Group TP6 presents a cutting-edge angle less than 45°, with a plano-convex section (fig. 6).

The TFU T can also be oval (TO1) or straight (TR1) in plan. In the first case, the cutting edge angle is greater than 45° with a biconvex section. In the second case, the angle is also greater than 45° but with a biplane section (fig. 7).

Oblique opposition between TFU T and TFU P

Five tool types correspond to this functional structure. The cutting edge, pointed or oval in plan, extends over one-third of one edge and two-thirds of the opposite edge, creating structural asymmetry.

If the edge angle of the TFU T is greater than 45°, then the section is biconvex (OP1) (fig. 7). If the cutting angle is less than 45°, the section can be biplanar and symmetrical (OP2) or asymmetrical (OP3).

In cases where the TFU T is oval in plan, when the cutting angle is greater than 45° the section is biconvex (OO1). If the angle is less than 45°, the section is biplanar and symmetrical (OO2) (fig. 8).

Bifacial tools with multiple cutting edges

One biface bears 3 TFU T, including a notch on the mesial part of one edge, as in the two previously described cases. Furthermore, this bifacial blank comprises type OP3 TFU T/TFU P pairing on the apical end and another OO1 type on the basal end (fig. 9a).

Another biface is part of an advanced reduction cycle (RI = 0.53; SDI = 0.02048281), as is clearly visible in the superimposition of removals, particularly in the mesial zone, and their

detachment angles. In its last technical state, two shaping phases (one apical and the other basal) form the two TFU T. The apical part is type TP5, while the basal part is type TR1 (fig. 9b).

In one case (fig. 9c), the tool bears a similar first TFU T/TFU P pair to the previously described TP4 type. This is associated with a « notch » type arrangement on one edge, consisting of the detachment of an inward removal creating a concave edge in plan and plano-concave in section with an angle greater than 45°. This second TFU T is longitudinally opposed to the TFU P. It is important to emphasise that the produced flake can also be the functional aim, i.e., two tools: a notch on a bifacially-shaped blank and a flake with a peripheral cutting edge and a thick butt, are produced in one stroke.

The same type of TFU T type « notch » is also present on another biface, associated with a TFU T/TFU P pair corresponding to type OO1 (fig. 9d).

Some constants in bifacial production at Arago Cave

For most of the 24 tools with a single TFU T, the latter presents a pointed morphology (n = 19), more rarely oval (n = 4) and occasionally rectilinear (n = 1). The configuration of the TFU T and TFU P is mostly transverse (n = 15), or oblique (n = 9). Only three multiple tools with a TFU T notch on one edge show a longitudinal configuration for the TFU pair.

Results: Variability of bifacial tool types over time

Distribution of the different types of bifacial tools as a function of time

Tool types TP1, TP2, TP5, TR1, OP3 and OO2 are only present in the archaeostratigraphic subunits of Unit 1, correlated with MIS 14. In contrast, tool types TP4, TP6 and TO1 are only present in Unit 3, correlated with MIS 12 (tab. 3).

The bifacial tools with several active areas are from the same chronological bracket. All three tools with a TFU T in lateral position belong to the archaeostratigraphic subunits of Unit 3 (G3, G1, E4).

This may reflect differences in the use of bifacial shaping for tool production over time. However, we must be cautious as not all tool types are present in all the archaeostratigraphic subunits of Unit 1 and 3. Therefore, parameters other than time clearly influence the variety of functional objectives involved in bifacial shaping.

Furthermore, types TP3, OP1, OP2 and OO1 (and OP3 if tools with multiple TFU T are also taken into consideration) are present in the archaeostratigraphic subunits of MIS 14 and 12 (tab. 3). Is this discontinuous presence over time in the stratigraphy of Arago Cave linked to changes in techno-cultural traditions or to the variability of activities carried out in the cave?

Functional but also dimensional and production differences

Technical traditions can be assessed through the analysis and comparison of *chaînes opératoires* and the volumetric characteristics of tools.

Raw material choices

Both units use the same raw materials for bifacial shaping: flint, limestone, quartzite, sandstone, hornfels and basalt (tab. 1). The petrographic choices are therefore varied. There is a specific choice of raw material for only one type of tool: OP3, made of flint (but only two pieces). The raw material module chosen is often indeterminable due to the technical investment (13 cases, including 11 in Unit 1). The use of flake as blank is documented in both Unit 1 (3 cases) and Unit 3 (2 cases). The use of pebbles/cobbles is only identified in unit 3 (5 cases).

Production technique

In 4 cases, all from Unit 1, the morphology of the removal negatives (fracture initiation, flatness, invasion) suggests the use of a soft hammer for shaping. In the case of the two bifaces from AU Q1, this is confirmed by flake analysis (Viallet *et al.*, 2012). This technique is used for tool types TP1, TP3, OP2 and OP3. It is never exclusive to one type of tool.

Production methods

Shaping can be facial or lateral. The latter was facial in 9 cases and lateral in 16 cases. In 2 cases it was both facial and lateral and in 1 case it could not be determined (tab. 1). Facial shaping is specific to the production of tool types OP2 and OP3. Lateral shaping is specific to tool types TP3, TP4, OP1 and tools with several TFU T. At stratigraphic unit scale (Units 1 and 3), differences in production methods exist. Facial shaping is therefore almost exclusively in Unit 1. Lateral shaping is better represented in Unit 3. In 12 cases, the shaping process is accompanied by a phase in which certain parts of the tool are retouching. Most of the bifaces in Unit 1 (10 cases) were made using this technique. Tools from AU P3 are always retouched. Of the tool types present in Unit 1 and Unit 3, OP1 and OO1 have the same production characteristics: use of hard hammer, lateral shaping and no retouching phase. Type TP3 has lateral shaping and no retouching phase. A difference (between units 1 and 3) is the use of the soft hammer in addition to the hard hammer in unit 1. This difference in hammers can also be seen in type OP2, where the shaping is facial, combined with one (or two) retouching phases.

Morphological data

This higher technical investment in Unit 1 is only partially reflected by morphological metric data. The bifaces strictly associated with Unit 1 (TP1, TP2, TP5, TR1, OP3 and OO2) are generally shorter, narrower and especially thinner than those in Unit 3 (TP4, TP6 and TO1). This observation is particularly true for types TP2, TP5, TR1, OP3 and OO2 compared to types TP4 and TO1. Types TP1 and TP6 have comparable volumes (fig. 10).

The observation of the same variables within the tool types found in Units 1 and 3 (TP3, OP1, OP2 and OO1) also does not allow the identification of clear morphological trends (fig. 11).

Due to the small size of the sample, it is not possible to highlight any clear morphological variability between Units 1 and 3 of the Caune de l'Arago, beyond that which led to the creation of the different tool types.

Discussion

Variations indicative of different functional objectives

The analysis of the *chaînes opératoires* does not reveal specific characteristics, but rather trends, as no technique, method or choice of raw materials is exclusively correlated with only one of the two units. However, it should be noted that a soft hammer was only used in Unit 1 and lateral shaping was only used in Unit 3. In addition, the use of flake as a blank for bifacial production is clearly more documented in Unit 1.

This variability is clearer from a technical-functional perspective. The bifaces at Arago Cave actually represent thirteen different tool types. Four of the tool types are found in both units, six tool types are specific to Unit 1 and three to Unit 3. This demonstrates the adaptability of bifacial shaping and shows that this technical mode encompasses the production of different tool types.

The variability of bifaces between the two units of Arago Cave is therefore essentially explained by the diversity of functional objectives. But, within each functional group of bifacial tools, the number of artefacts is very limited (maximum 3). It is therefore difficult to determine whether the variations in the *chaînes opératoires* are constrained by the structures and functional conformations of the tool groups or by the application of technical traditions.

The variability of functional objectives associated with the production of bifaces may reflect technical traditions, influenced or not by the environment, but may also highlight the variability in the use of the cavity (duration and type of occupation).

The environment as a factor of variation

The influence of the environment, in particular climatic parameters, in a context of alternating Middle Pleistocene glacial and interglacial phases, can be put forward to explain the development of human occupations (Moncel *et al.*, 2018). In this way, the presence of Acheulean techno-complexes in the north of the European continent would be linked to phases of climatic warming allowing populations to settle in northern plains (Moncel *et al.*, 2016). The long period of climatic warming in MIS 11 would also have been a favourable time for technological development, as reinforced social relations favour innovation and the diffusion of knowledge (Davis and Ashton, 2019 ; Sassoon *et al.*, 2023).

While environmental stability is conducive to the development of human groups and temperate periods are more propitious for their expansion towards the northern plains (Ashton and Davis, 2021), this cannot be construed as the sole cause of technical innovation. The tempo of climate change seems to be too long in comparison to human generational turnover for the former to have a direct influence on the latter's technological innovation. Moreover, the chronological resolution of archaeological observations for the Lower Palaeolithic is probably insufficient to detect any effect of climate on technology. In addition, it appears that technical evolution is also part of a process parallel to the external environment as defined by A. Leroi-Gourhan (1943, 1945). In this sense, and beyond the notion of trend put forward by the same author, technical objects evolve according to their own structural requirements (Simondon, 1958 ; Boëda, 2005 ; 2013 ; 2021).

In the case of Arago Cave, bifaces are only present in the archaeological levels of the stratigraphic units corresponding to glacial phases. Indeed, the warm phase of Unit 2, whether interglacial or interstadial (Lebreton, 2018), does not contain bifaces. However, this somewhat

simplistic scheme overlooks many other factors; firstly because several levels of the cold units 1 and 3 do not contain bifaces either (M, N, O, K and F); and secondly, because the detailed analysis of the lithic assemblages reveals the presence of biface production waste in some levels of Unit 2 and in level L of Unit 1 (Capellari *et al.*, 2021). Therefore, the climate does not appear to have a direct impact on the presence of bifacial production at Arago Cave.

Impact of occupation duration and site function

Site function is often put forward to explain the variability of technical systems during the Acheulean (Moncel *et al.*, 2015). The variability of bifacial production at Cagny-la-Garenne is interpreted as a sign of its function as a production site (Lamotte and Tuffreau, 2001). Our perception of the variability of bifacial shaping may therefore be influenced by site function.

The archaeozoological and anthropological data (although fragmentary in certain levels), indicate three occupation temporalities for Arago Cave, always associated with hunting practices: short occupation (bivouac), seasonal occupation and long-term occupation (Lumley *et al.*, 2004 ; 2015). Short-term occupations, alternating between humans and other predators, are identified as much in the cold phase of Unit 1 (M, N, O, K) as in the warm phase of Unit 2 (H, I, J). On the other hand, the longer occupations of the cavity are exclusively linked to the cold phases of Units 1 and 3 (Q, P, G, F, E). It is therefore not possible to establish a causal relationship between occupation duration and climatic phases, with the exception of the warming in Unit 2, which is only associated with brief visits to the cave. However, the presence of bifaces in the cave is associated with long-duration occupations (Q, P, G and E), although this correlation does not imply a causal relationship, since the increase in occupation duration necessarily multiplies the chances of abandoning these tools in the cave.

The small quantities of bifaces in the long-term occupation levels, associated with bifacial production waste in the seasonal or short-term occupation levels, back up the idea of a mobile tool, designed for use for activities outside the cave, as proposed for Unit 1 on a strictly technological basis (Viallet *et al.*, 2022). Beyond the environmental influence or occupation duration, we should perhaps seek to explain the diversity of the functional objectives of bifacial production by assessing the variability of the activities practised within the site. Unfortunately, despite an exceptional record for the period, the analytical homogeneity of the different levels of Arago Cave is still insufficient to achieve this level of interpretation.

Conclusions

Observations of the tools produced by bifacial shaping in Unit 1 and Unit 3 reveal morphological variability. Based on the technical-functional analysis, we propose that this variability is related to different functional objectives. Production techniques and methods are neither specific to a particular stratigraphic unit – except for the use of soft hammers only in the unit 1 – nor to a particular type of bifacial tool. Hard hammer percussion is predominant. In both units, there is no exclusive preference for lateral or facial modes of volume assessment during the shaping process. Finally, the choice of raw materials shows that hominids in both units had similar knowledge of the mineral environment. The only morpho-technical difference between Units 1 and 3 that cannot be explained by functional objectives, concerns a longer shaping process in the unit 1, with frequent retouching phases.

Consequently, the differences between Units 1 and 3 of Arago Cave relate - in part - to the objectives of bifacial production. These production objectives may be conditioned, on the one hand, by different technical traditions and, on the other, by variations in site function and how it is exploited. Unfortunately, in the absence of more precise data on site occupation modes, particularly for the levels of Unit 1, it is not possible to pinpoint the influence of technical traditions. We can merely note that there is no discontinuity in hominid knowledge of the mineral environment or in the technology of bifacial production between the lower and upper levels of the middle complex at Arago Cave.

At a broader scale, the data of Arago Cave demonstrates that several types of tools correspond to the handaxe appellation. The analysis carried out here confirms the idea that the term "handaxe" does not have a functional meaning and brings new elements of discussion to the debate. The term only refers to a technical mode of production: bifacial shaping, which generates the production of different types of tools. This is not a mere semantic difference: to use the word biface instead of bifacial shaping is, for example and according to actualist analogies, to equate a knife with the whole of metallurgy. At a broader scale than Arago Cave, microwear analysis shows that bifacial shaping is used to produce knives, axes and picks. Technological analysis shows that depending on chronological and geographical sectors, these tools may be similar or different, part of an evolutionary cycle or not. In sum, they show all the variability inherent to a technical mode. The analysis of the functional variability within this technical mode at a global scale will lead to the production of new data on the Lower Palaeolithic. It is time to move beyond research that considers the "biface" as a single, possibly versatile tool, and to go beyond questions of raw materials, know-how, sites and tools function to account for variability.

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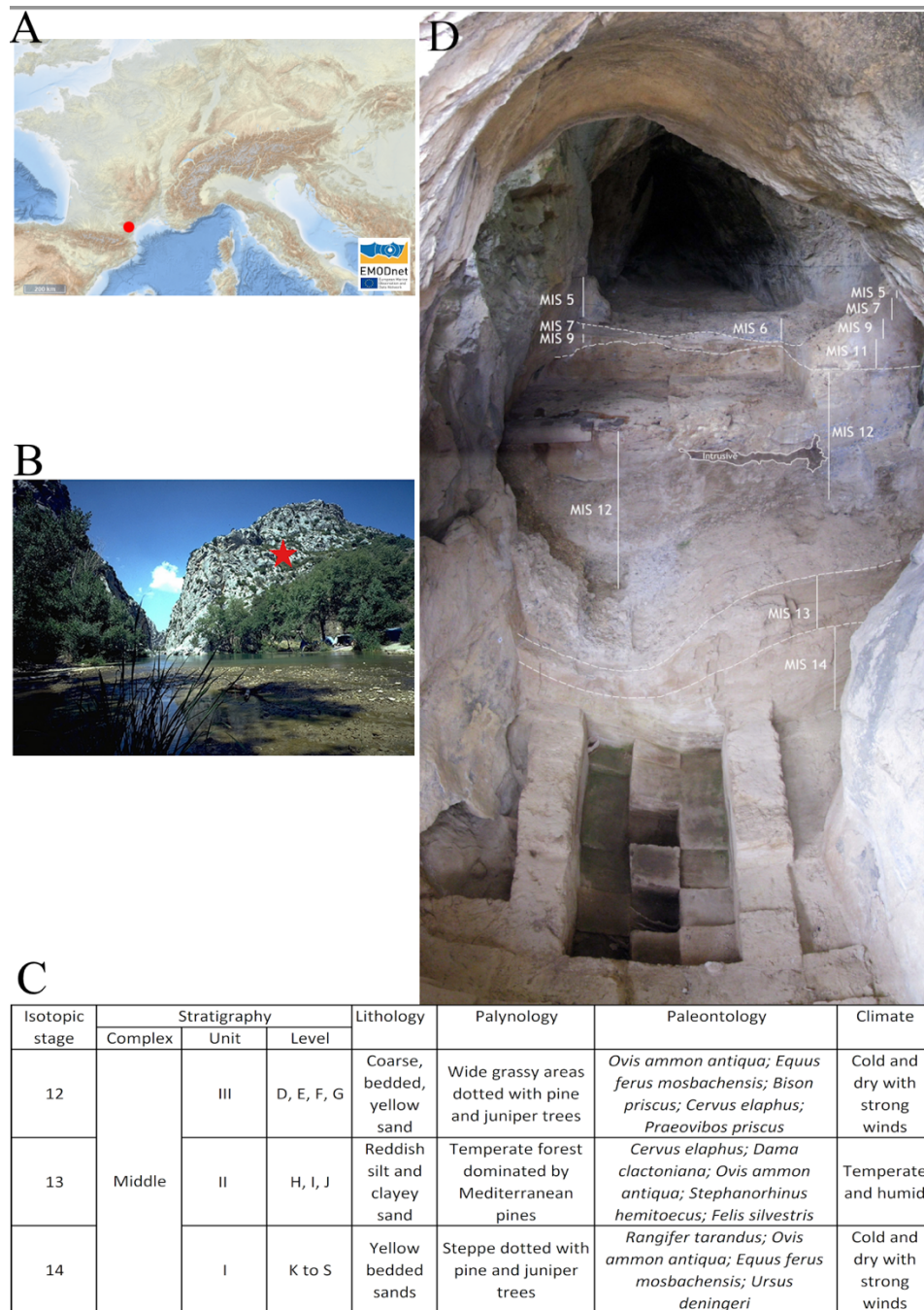


Fig 1 : Localisation géographique de la Caune de l'Arago, dans le sud-est de la France, au sein du massif des Corbières (A, EMOD viewer). Position de la cavité dans les gorges des Gouleyrous (B, cliché H. De Lumley). Récapitulatif des principales caractéristiques du complexe moyen (C, d'après Perrenoud (dir.), 2010). Stratigraphie du remplissage de la Caune de l'Arago, avec les attributions chronologiques des différents ensembles (D, in Viallet et al., 2022).

Geographic location of the Caune de l'Arago, in south-eastern France within the Corbières massif (A, EMOD viewer). Location of the cave in the Gouleyrous gorges (B, photograph H. De Lumley). Summary of the main characteristics of the medium complex (C, after Perrenoud (dir.), 2010). Stratigraphy of the deposit of the Caune de l'Arago, with mention of chronological attributions (D, in Viallet et al., 2022).



Fig 2 : Exemples d'artefacts en cornéenne présentant une forme amygdaloïde, mais dont la conservation ne permet pas l'attribution au groupe des bifaces (de haut en bas : C14_3822 ; C15_633 ; C17_359 ; E16_4609 ; I12_3728). (Clichés D. Dainat, CERP Tautavel)

Examples of hornfels with an amygdaloid shape, but whose conservation does not allow them to be attributed to the biface group (from top to bottom: C14_3822; C15_633; C17_359 ; E16_4609 ; I12_3728). (Photograph by D. Dainat, CERP Tautavel)

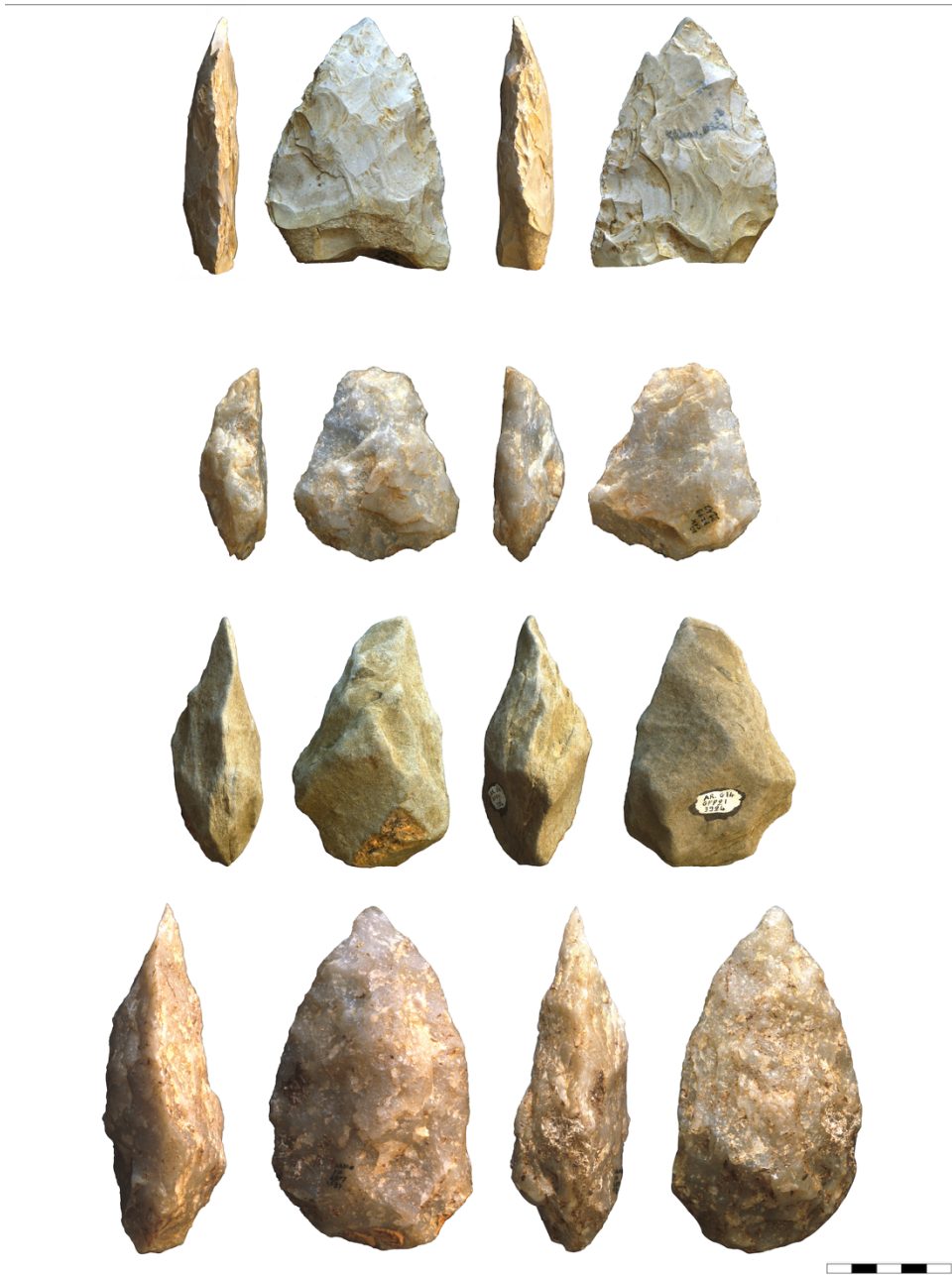


Fig 3 : Exemples de bifaces issus de l'ensemble I de la Caune de l'Arago (de haut en bas : E14_2807 ; F14_3242 ; G14_3924 ; E16_4597). (Clichés D. Dainat, CERP Tautavel)

Examples of bifaces from group I of the Caune de l'Arago (from top to bottom: E14_2807; F14_3242; G14_3924; E16_4597). (Photograph by D. Dainat, CERP Tautavel)



Fig 4 : Exemples de bifaces issus de l'ensemble III de la Caune de l'Arago (de haut en bas : D18_1012 ; H15_49 ; E17_626 ; I19_722). (Clichés D. Dainat, CERP Tautavel)

Examples of bifaces from group III of the Caune de l'Arago (from top to bottom: D18_1012; H15_49; E17_626; I19_722). (Photograph by D. Dainat, CERP Tautavel)

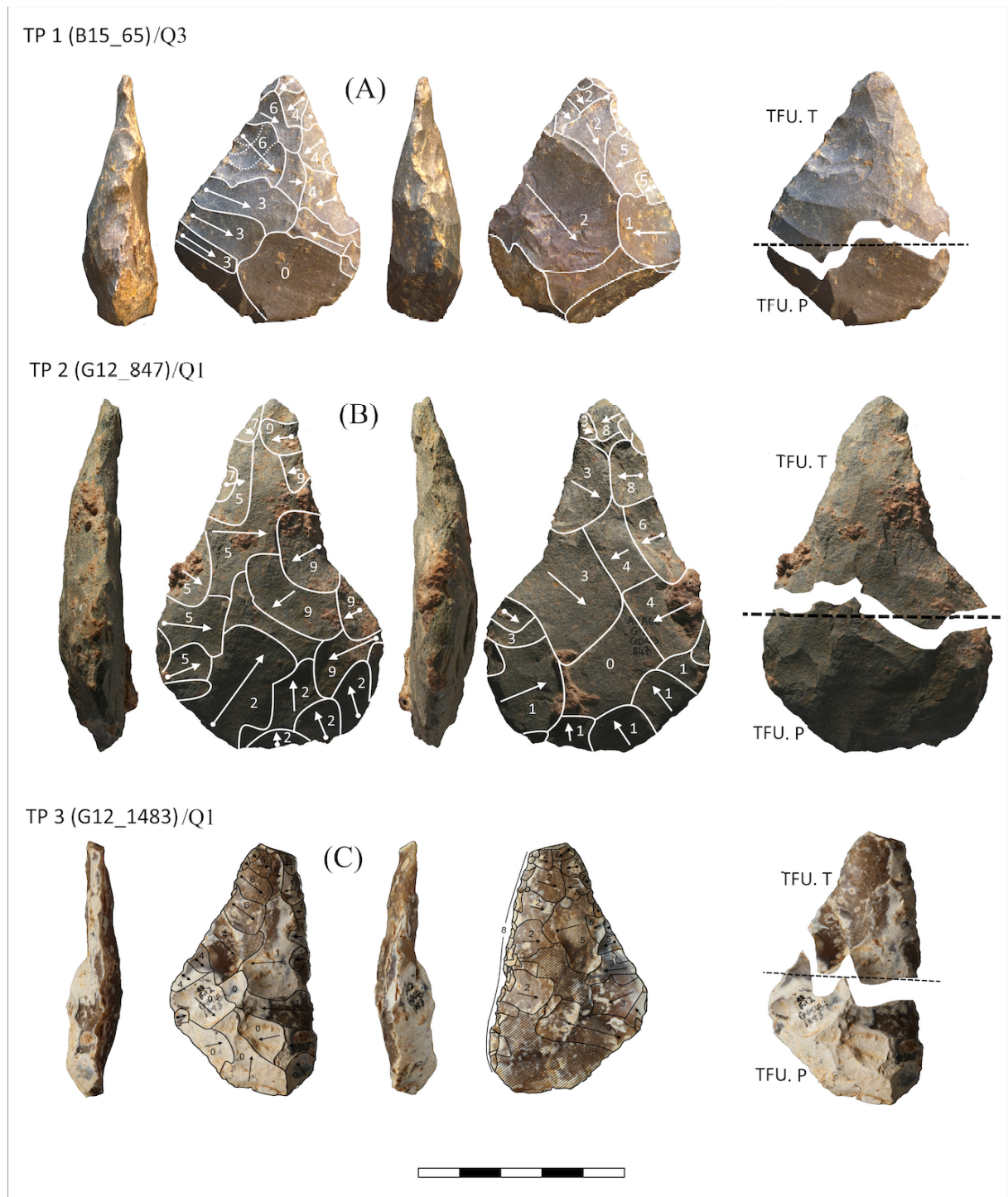


Fig 5 : Schéma diacritique et mise en évidence des UTF Transformatives et Préhensives pour trois techno-types de bifaces. Opposition Transversale entre UTF CT et CP et morphologie Pointue en plan (TP) ; (de haut en bas : B15_65 / TP1 / UA Q3 ; G12_847 / TP2 / UA Q1 ; G12_1483 / TP3 / UA Q1)

Diacritic scheme and identification of Transformative and Prehensive TFU for three biface techno-types. Transversal opposition between TFU T and P and Pointed morphology in plan view (TP); (from top to bottom : B15_65 / TP1 / AU Q3 ; G12_847 / TP2 / AU Q1 ; G12_1483 / TP3 / AU Q1).

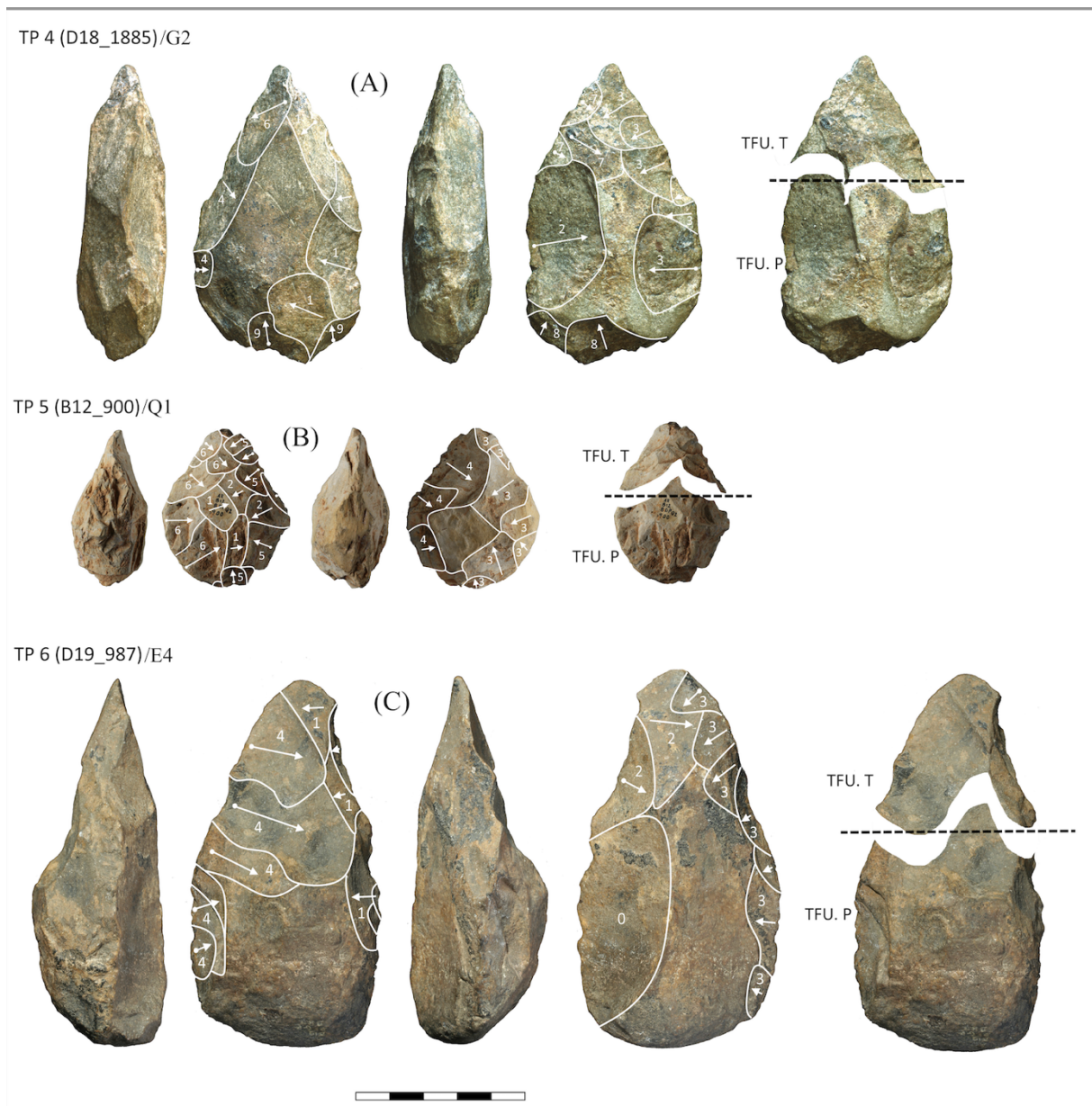


Fig 6 : Schéma diacritique et mise en évidence des UTF Transformatives et Préhensives pour trois techno-types de bifaces. Opposition Transversale entre UTF CT et CP et morphologie Pointue en plan (TP) ; (de haut en bas : D18_1885 / TP4 / UA G2 ; B12_900 / TP5 / UA Q1 ; D19_987 / TP6 / UA E4).

Diacritic scheme and identification of Transformative and Prehensive TFU for three biface techno-types. Transversal opposition between TFU T and P and Pointed morphology in plan view (TP); (from top to bottom : D18_1885 / TP4 / AU G2 ; B12_900 / TP5 / AU Q1 ; D19_987 / TP6 / AU E4).

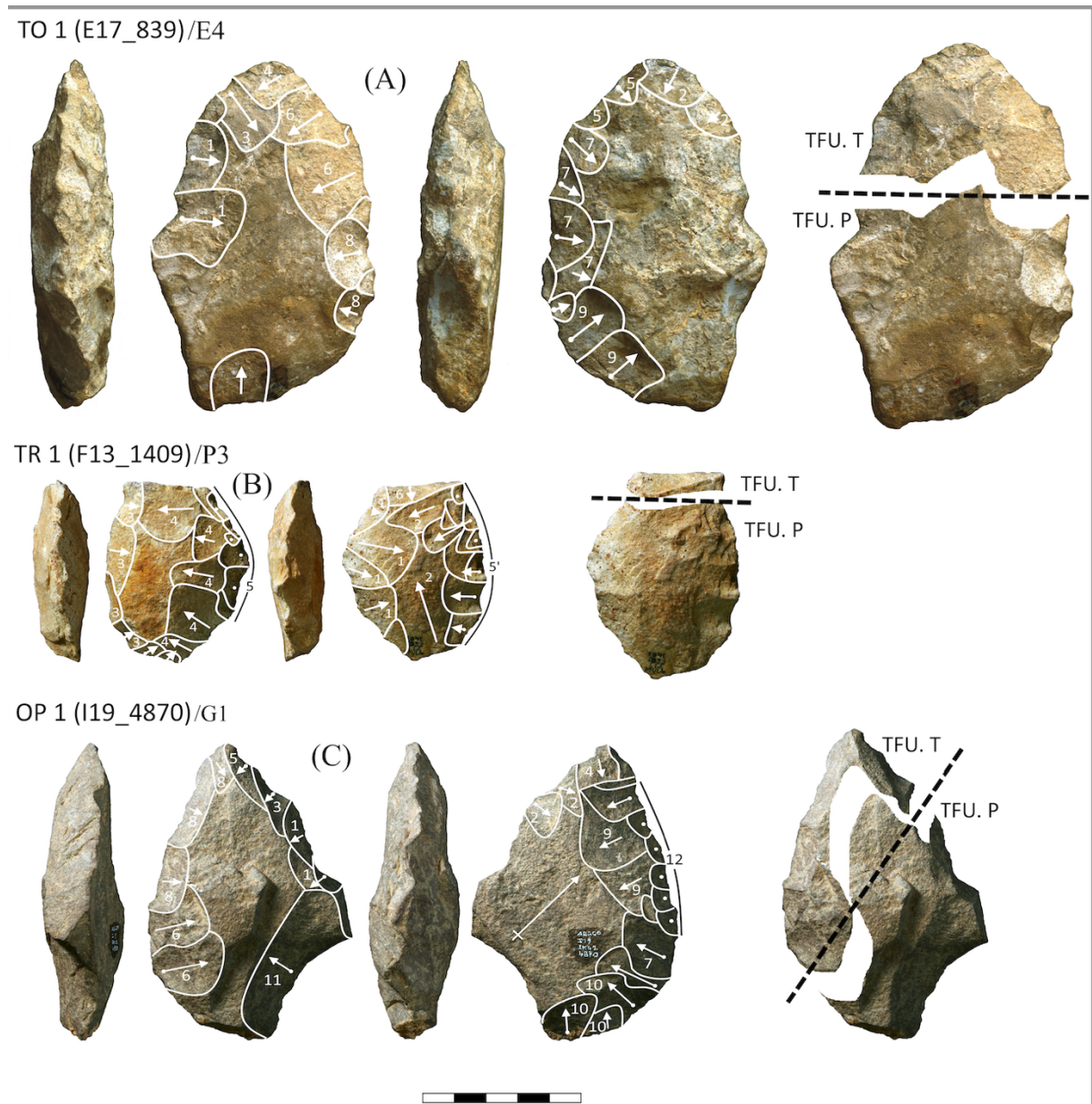


Fig 7 : Schéma diacritique et mise en évidence des UTF Transformatives et Préhensives pour trois techno-types de bifaces. Opposition Transversale entre l'UTF CT et CP, morphologie Ovale en plan : TO1 (E17_839 / UA E4) ; Opposition Transversale et morphologie Rectiligne : TR1 (F13_1409 / UA P3) ; Opposition Oblique et morphologie Pointue : OP1 (I19_4870).

Diacritical scheme and identification of Transformative and Prehensive TFU for three biface techno-types. Transversal opposition between TFU T and P, Oval morphology in plan: TO1 (E17_839 / AU E4); Transversal opposition and Rectilinear morphology: TR1 (F13_1409 / UA P3); Oblique opposition and Pointed morphology: OP1 (I19_4870 / UA G1).

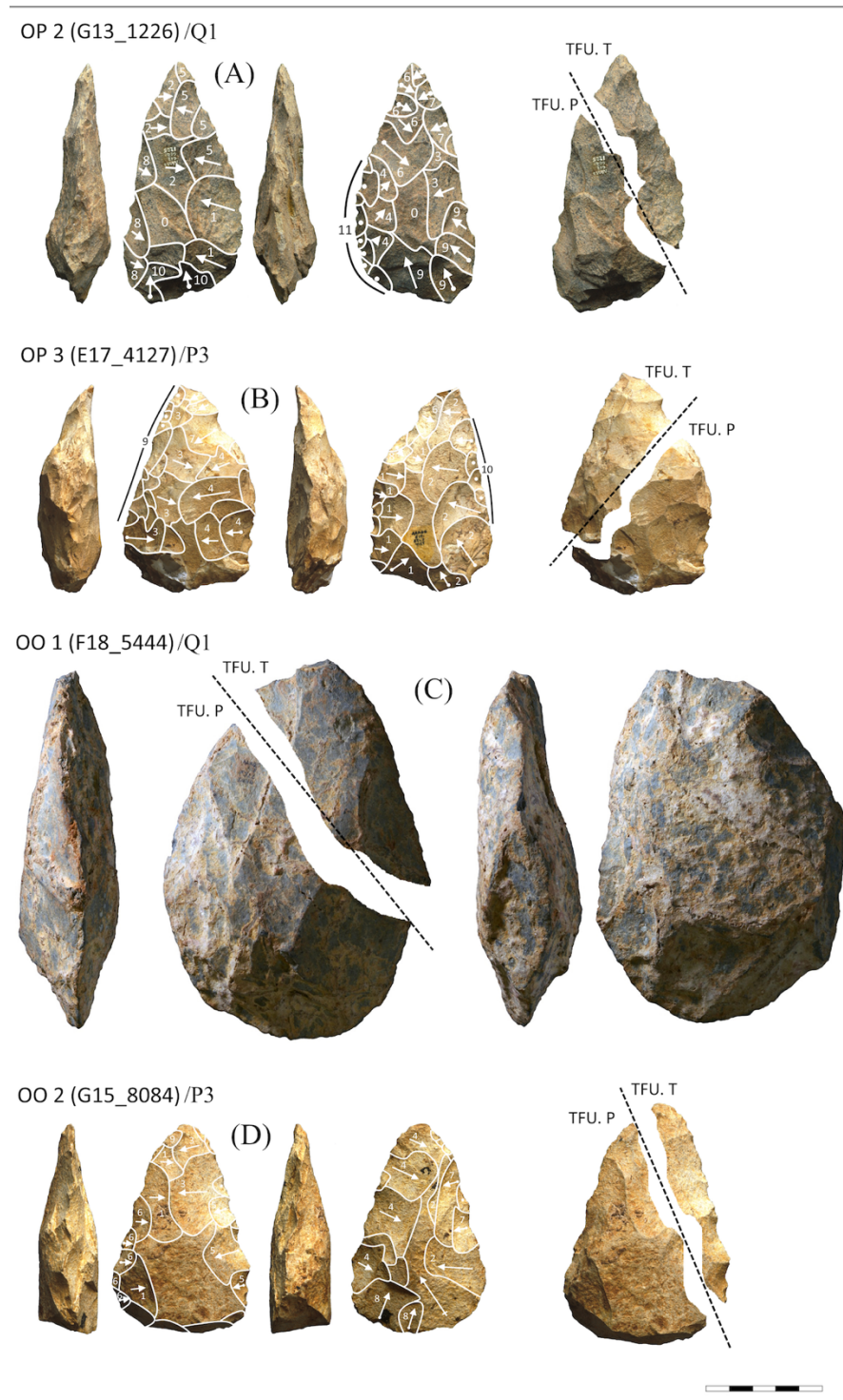


Fig 8 : Schéma diacritique et mise en évidence des UTF Transformatives et Préhensives pour quatre techno-types de bifaces. Opposition Oblique entre UTF CT et CP, morphologie Pointue en plan : OP1 (G13_1226 / UA Q1) ; OP2 (E17_4127 / UA P3) ; opposition Oblique, morphologie Ovalaire : OO1 (F18_5444 / UA Q1) ; OO2 (G15_8084 / UA P3).

Diacritic scheme and identification of Transformative and Prehensive UTF for four biface techno-types. Oblique opposition between TFU T and P, Pointed morphology in plan: OP1 (G13_1226 / AU Q1); OP2 (E17_4127 / AU P3); Oblique opposition, Oval morphology: OO1 (F18_5444 / AU Q1); OO2 (G15_8084 / AU P3).

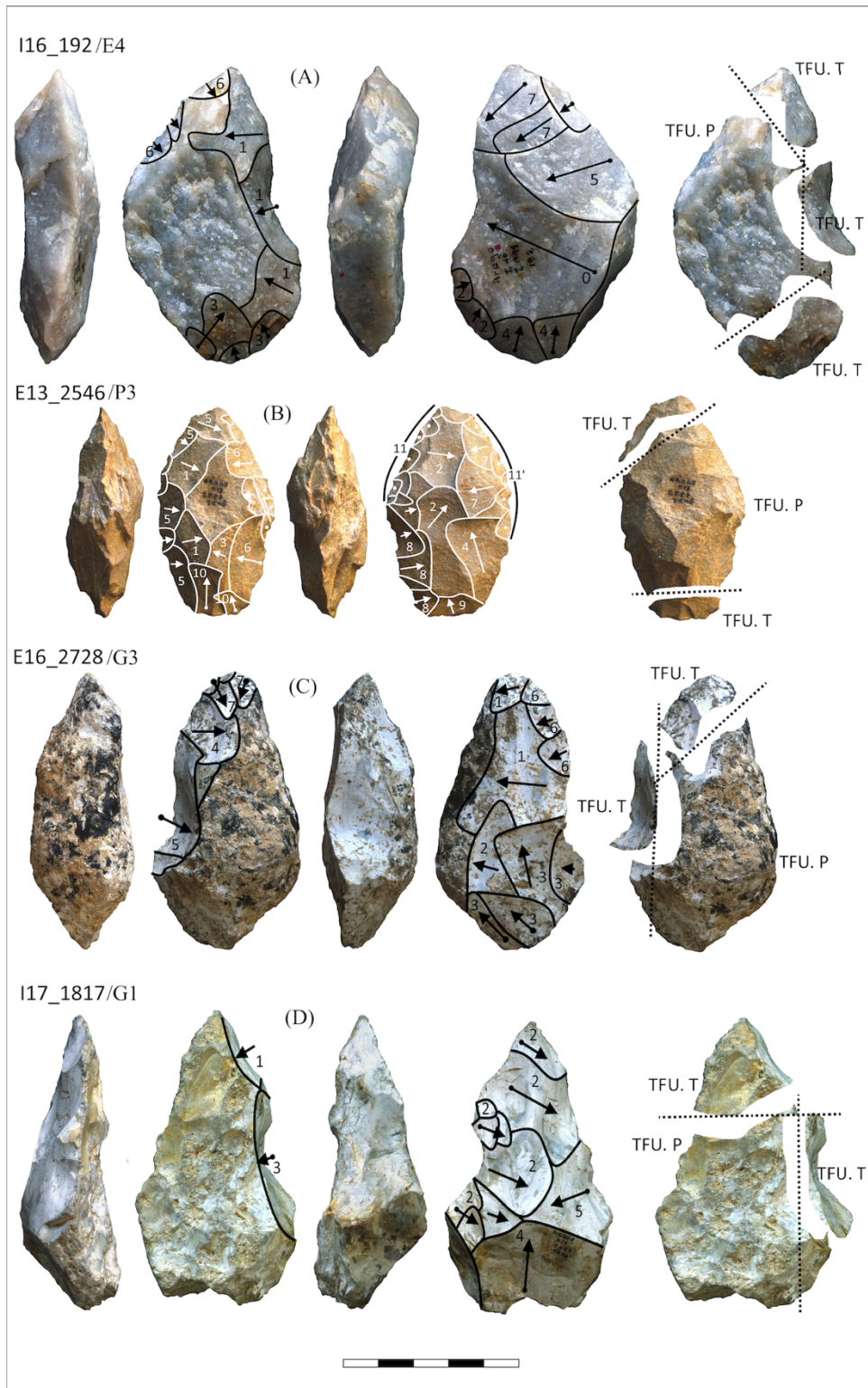


Fig 9 : Schéma diacritique et mise en évidence des UTF Transformatives et Préhensives pour quatre techno-types de bifaces avec plusieurs UTF CT.

Diacritic scheme and identification of Transformative and Prehensive TFU for four bifacial techno-types, with several TFU T.

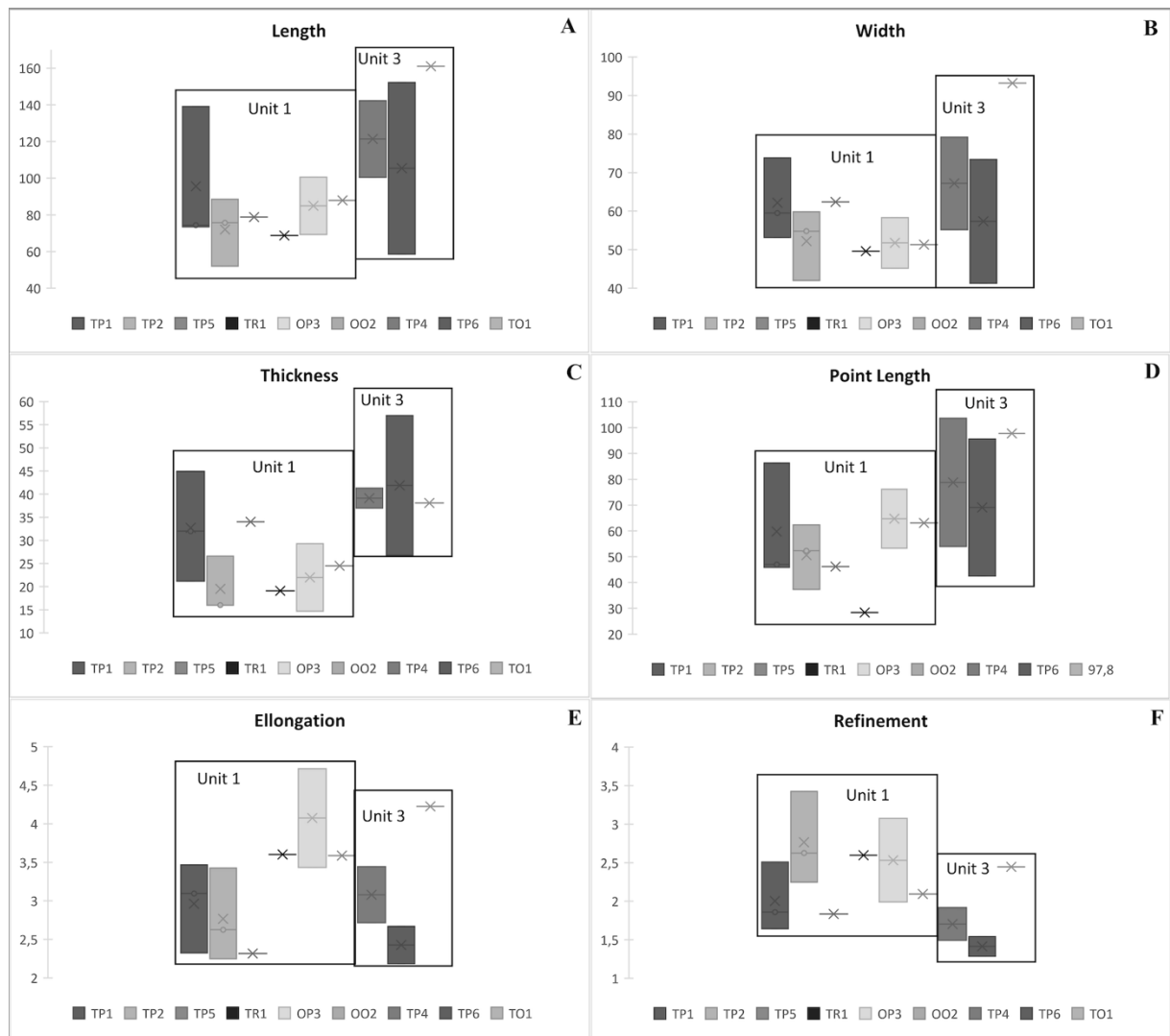


Fig 10 : Boîtes à moustache de différentes variables de description volumétrique entre les ensembles I et III, à partir des types d'outils spécifiques à l'un ou l'autre ensemble.

Boxplots of different volumetric description variables between units I and III, based on the types of tools specific to one or other unit.

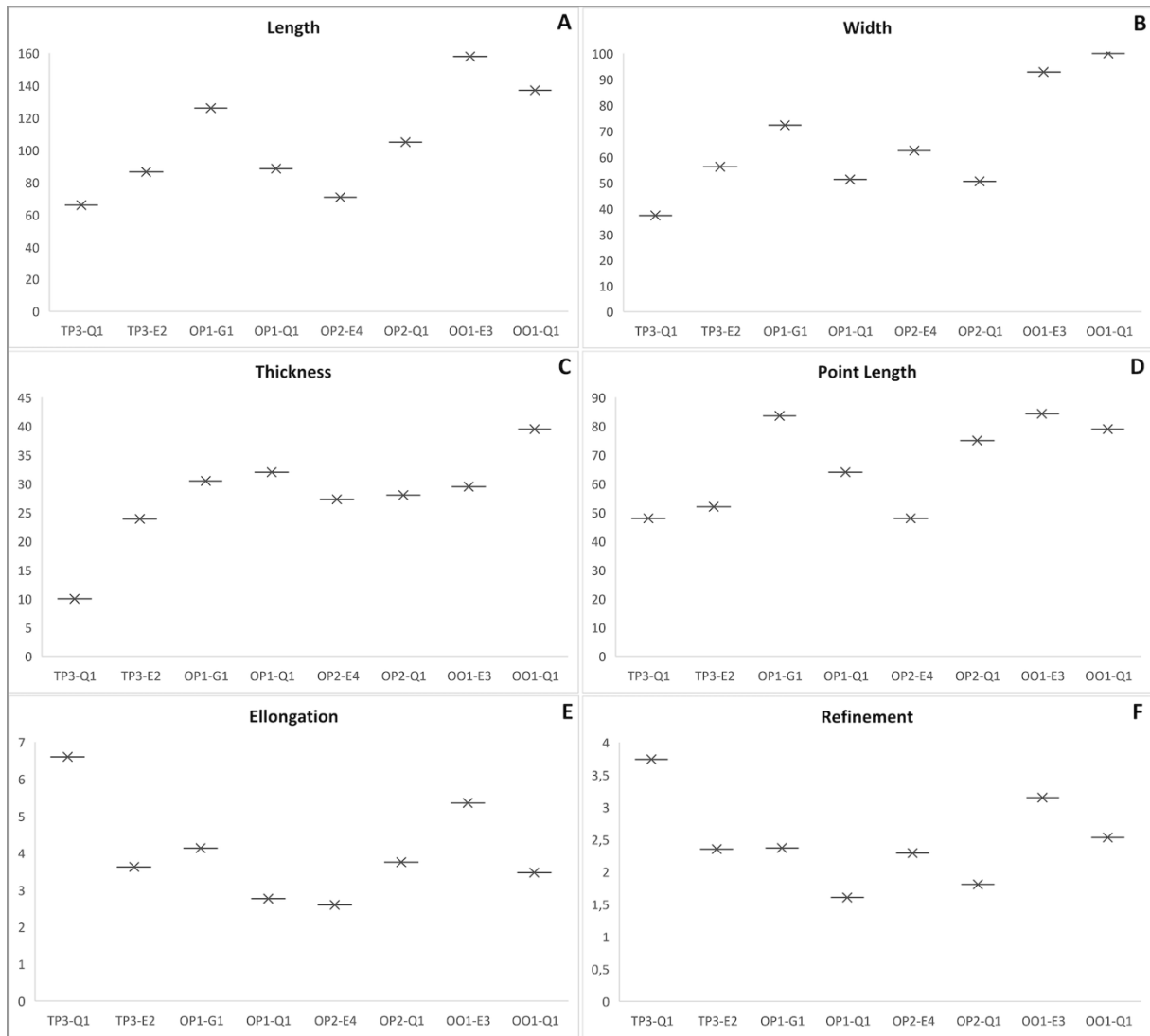










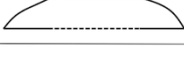




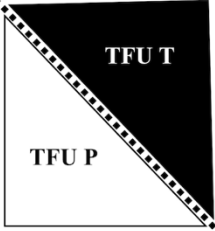


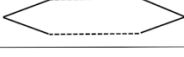
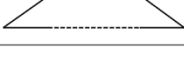



Fig 11 : Caractéristiques volumétriques des techno-types présents dans les deux ensembles stratigraphiques.

Volumetric characteristics of the techno-types present in the two stratigraphic units.

Name	UA	Raw Material		Volume						Production			TFU T characteristic			Tool-type
		Petrography	Type	Length	Width	Thickness	Point length	Elongation	Refinement	Percussion	Method	Retouch	Angle	Profil	Section	
B15.65	Q3	Jasper	Flake	73,5	53,2	21,2	47	3,47	2,51	Hard and Soft	Facial	2 stages	>45°	Scalloped	Biconvex	TP1
E16.4597	Q1	Quartzite	Indet'	139	73,8	44,9	86,3	3,10	1,64	Hard	Facial	No	>45°	Rectilinear	Biconvex	
B13.1440	Q1	Limestone	Indet'	74,4	59,5	32	45,9	2,33	1,86	Hard	Lateral	No	>45°	Irregular	Biconvex	
F14.3242	P3	Quartzite	Indet'	75,7	59,8	26,6	52,3	2,85	2,25	Hard	Facial	2 stages	>45°	Rectilinear	Convex-Plane	TP2
I11.1646	Q1	Quartz	Indet'	52	42	16	37,3	3,25	2,63	Hard	Facial	No	>45°	Rectilinear	Convex-Plane	
G12.847	Q1	Hornfels	Indet'	88,5	54,8	16	62,3	5,53	3,43	Hard	Mix	No	>45°	Rectilinear	Convex-Plane	
G12.1483	Q1	Flint	Slab	66	37,4	10	48	6,60	3,74	Hard and Soft	Lateral	2 stages	<45°	Rectilinear	Biplane	TP3
E17.626	E2	Hornfels	Indet'	86,6	56,2	23,9	52	3,62	2,35	Hard	Lateral	No	<45°	Scalloped	Biplane	
D18.1885	G2	Basalt	Pebble	142,2	79,2	41,3	103,6	3,44	1,92	Hard	Lateral	No	>45°	Irregular	Trihedral	TP4
D18.1012	G1	Quartzite	Pebble	100,5	55,2	37	54	2,72	1,49	Hard	Lateral	No	>45°	Irregular	Trihedral	
B12.900	Q1	Limestone	Indet'	78,8	62,4	34	46,2	2,32	1,84	Hard	Lateral	1 stage	>45°	Rectilinear	Biconvex	TP5
D19.987	E4	Limestone	Pebble	152,2	73,4	57	95,6	2,67	1,29	Hard	Lateral	No	<45°	Irregular	Convex-Plane	TP6
H15.49	E1	Flint	Indet'	58,6	41,3	26,8	42,6	2,19	1,54	Hard	Mix	2 stages	<45°	Rectilinear	Convex-Plane	
E17.839	E4	Sandstone	Slab	161	93,2	38,1	97,8	4,23	2,45	Hard	Lateral	No	>45°	Irregular	Biconvex	TO1
F13.1409	P3	Sandstone	Indet'	68,8	49,6	19,1	28,4	3,60	2,60	Hard	Facial	2 stages	>45°	Rectilinear	Biplane	TR1
I19.4870	G1	Quartzite	Flake	126	72,3	30,5	83,6	4,13	2,37	Hard	Lateral	No	>45°	Irregular	Biconvex	OP1
G14.3924	Q1	Hornfels	Indet'	88,6	51,3	32	64	2,77	1,60	Hard	Lateral	No	>45°	Rectilinear	Biconvex	
I19.722	E4	Flint	Pebble	70,9	62,5	27,3	48	2,60	2,29	Hard	Facial	2 stages	<45°	Rectilinear	Biplane	OP2
G13.1226	Q1	Basalt	Indet'	105	50,6	28	75	3,75	1,81	Hard and Soft	Facial	1 stage	<45°	Scalloped	Biplane	
E14.2807	P3	Flint	Slab	60,3	45,2	14,7	53,3	4,71	3,07	Hard and Soft	Facial	2 stages	<45°	Rectilinear	Biplane	OP3
E17.4127	P3	Flint	Indet'	100,6	58,3	29,3	76,1	3,43	1,99	Hard	Facial	1 stage	<45°	Rectilinear	Biplane	
E19.488	E3	Sandstone	Pebble	157,9	92,8	29,5	84,3	5,35	3,15	Hard	Lateral	No	>45°	Irregular	Biconvex	OO1
F18.5444	Q1	Hornfels	Flake	137	100	39,5	79	3,47	2,53	Hard	Indet'	No	>45°	Rectilinear	Biconvex	
G15.8084	P3	Basalt	Flake	87,9	51,3	24,5	63,06	3,59	2,09	Hard	Lateral	2 stages	<45°	Rectilinear	Biplane	OO2
I17.1817	G1	Flint	Nodule	93	56,6	37,1	62	2,51	1,53	Hard	Lateral	No				Several TFU T
E16.2728	G3	Flint	Nodule	108,4	56,6	37,5	74,1	2,89	1,51	Hard	Lateral	No				
I16.192	E4	Quartzite	Flake	120	68,6	30,7	74,9	3,91	2,23	Hard	Lateral	No				
E13.2546	P3	Quartzite	Indet'	83,5	44,7	27,9	44,5	2,99	1,60	Hard	Lateral	1 stage				

Tab 1 : Ensemble des données stratigraphiques, pétrographiques, technologiques et morphologiques des bifaces de la Caune de l'Arago.

All the stratigraphic, petrographic, technological and morphological data on the bifaces of the Caune de l'Arago.

STRUCTURE	CONFORMATION			TECHNO-TYPE
	PLAN	ANGLE	SECTION	
Transversal 	Punctiform 	> 45°		TP1 (n = 3)
		> 45°		TP2 (n = 3)
		< 45°		TP3 (n = 2)
	Punctiform 	> 45°		TP4 (n = 2)
		> 45°		TP5 (n = 1)
		< 45°		TP6 (n = 2)
Ovale 	> 45°		TO1 (n = 1)	
	Rectilinear 	> 45°		TR1 (n = 1)
Oblique 	Punctiform 	> 45°		OP1 (n = 2)
		< 45°		OP2 (n = 2)
		< 45°		OP3 (n = 2)
	Ovale 	> 45°		OO1 (n = 2)
		< 45°		OO2 (n = 1)

Tab 2 : Récapitulatif des structures fonctionnelles et des conformations des unités transformatives des bifaces de la Caune de l'Arago.

Summary of the functional structures and conformations of the transformative units of the bifaces from the Caune de l'Arago.

US	UA	TP1	TP2	TP3	TP4	TP5	TP6	TO1	TR1	OP1	OP2	OP3	OO1	OO2
Unit 1 (MIS 14)	Q3	■												
	Q1	■	■	■		■				■	■		■	
	P3		■						■	■	?	■	■	■
Unit 3 (MIS 12)	G2				■					■	?			■
	G1			?	■					■				■
	E4						■	■			■			
	E3												■	
	E2			■										
	E1						■							

Tab 3 : Récapitulatif de la présence des techno-types de bifaces en fonction des unités stratigraphiques et des ensembles de la Caune de l’Arago. Un rectangle gris indique la présence d’un techno-type.

Summary of the presence of biface techno-types according to stratigraphic units and assemblages in the Caune de l’Arago. The presence of a techno type is indicated by a grey rectangle.