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Microburins and fracture mechanics: the experimental production of Sauveterrian microliths

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SUMMARY - *Microburins and fracture mechanics: the experimental production of Sauveterrian microliths* - This work tries to describe and explain the techniques used to fashion Early Mesolithic microliths by studying a large number of lithic artefacts found in high mountain sites in the Trentino/Alto Adige region and in particular in the River Adige basin and by applying the laws of fracture mechanics to artefacts made with the microburin technique. This research, together with various experiments aimed at the reproduction of the individual work cycles (such as, for example, the preparation phases, the core management and the modification of the microlith supports) allowed the identification of a fundamental evolution in knapping techniques from the beginning of the Alpine Sauvetterian. Finally, the intention is to demonstrate the importance of the laws of mechanics as essential diagnostic criteria in a technological analysis of prehistoric lithic industry.

RIASSUNTO - *Il microbulino e la meccanica della frattura: la produzione sperimentale di armature Sauveterriane* - In questo contributo si cerca di descrivere e rendere comprensibili le tecniche utilizzate per il confezionamento di armature nel Mesolitico antico, attraverso lo studio di un elevato numero di manufatti litici che sono stati rinvenuti in alta quota nella regione Trentino/Alto Adige, in particolare nel bacino del Fiume Adige, ed applicando le leggi della meccanica della frattura nel caso di manufatti realizzati con la tecnica del microbulino. Questo studio, unitamente a varie sperimentazioni rivolte alla riproduzione dei singoli cicli di lavorazione (come, per esempio, le fasi di preparazione, la gestione dei nuclei e la modificazione di supporti per armature) ha permesso di individuare un'evoluzione fondamentale delle tecniche della scheggiatura, già a partire dall'inizio del Sauveterriano alpino. Infine si vuole dimostrare l'importanza delle leggi della meccanica come criteri diagnostici essenziali per le analisi tecnologiche sull'industria litica preistorica.

Key words: Sauveterrian, South-eastern alps, experimental fashioning of microlithts, fracture mechanics.
Parole chiave: Sauveterriano, Alpi sud-orientali, produzione sperimentale di armature, meccanica della frattura.

1. INTRODUCTION

Most of the high mountain Mesolithic sites are generally associated with hunting activities. In fact the lithic assemblies found there are mostly characterized by a large number of microliths and the waste products resulting from their production (Bagolini *et al*. 1983, Broglio 1990, Dalmeri & Lanzinger 1994).

The aim of this study is to reconstruct the techniques used in the production of the Sauveterrian microliths, taking into consideration the high number of lithic artefacts found at a high altitude in the Trentino/ Alto Adige region and in particular in the area near the River Adige basin (Kompatscher & Hrozny Kompatscher 2007), (Fig.1). This archaeological proof, found during systematic surveys, created the basis for a technological study of the lithic assemblies found and for an interpretation of the behavioural modes of the Mesolithic hunter-gatherers. In particular the author proposes a reconstruction of the choice of the cores, the principal chain of production, the knapping techniques used to make the required support and the retouching carried out. (We must point out that this study is limited by the fact that the flints collected are only a part of the lithic assemblage present on the individual sites. As a result the refitting necessary for the reconstruction of the chain of production was carried out in a limited way).

The raw materials used were almost all imported from a great distance that is from the Cretaceous rock formations in the southern alpine areas. The flints mostly come from the Biancone, the Scaglia variegata and the Scaglia rossa formations and are characterised by a crypto or microcrystalline structure suitable for good or at least decent knapping. They appear in layers or in isolated nodules (Bertola & Cusinato 2004) and from the point of view of their suitability, they appear to be a coherent and prestigious raw material. Accordingly, this work analyses above all the surface findings that can be traced to the aforementioned geological formations.

The local raw materials have different characteristics: those coming from the Livinallongo formation are of not high quality whereas those from the Cretacious Fanes formation are very split; the quartzite of the magmatic rocks and the rock crystal coming from the alpine divide were not taken

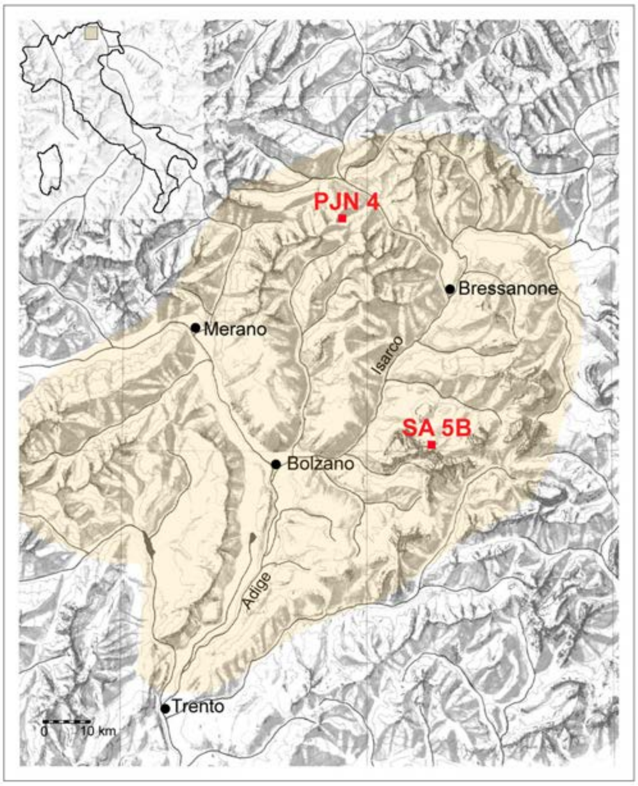

Fig. 1 - Geographic area e location of the sites SA 5B and PJN 4, objects of tecnologic analyses.
Fig. 1 - Area geografica di studio e localizzazione dei siti SA 5B e PJN 4, oggetto di analisi tecnologici.

into consideration as they have lithic technical characteristics that are very different and are often of poor quality.

The lithic technical properties of the three varieties mentioned at first, should result in analogous debitage techniques: the same shaping of the cores, the same percussion technique to produce the knapping products and the same method used in the final retouching procedure. This hypothesis is fully confirmed by the results obtained from a series of experiments carried out by the author.

2. CHRONOLOGICAL POSITION

In this work the chrono-cultural delimitation of the analysed lithic industry, attributed to the south alpine Early Mesolithic (Sauveterrian), was carried out from a typological and technological point of view and this allowed it to be distinguished from both the preceding cultural phase (Recent Epigravettian) and from the following Recent Mesolithic (Castelnovian). However it was not possible to discover any possible and eventual changes in work techniques coming about during the Early Mesolithic.

3. METHODOLOGY

After having consulted, as much as possible, previous publications especially those of F. Fontana (2009) and U.Wierer (2008) on the technology and the mechanics of fractures in the Early Mesolithic and generally (Faulkner1972), the author carried out a series of experiments to be able to reconstruct the techniques and the work phases used in the production of the microliths. The various phases of these experiments are not presented here in the order of the chain of production that is starting with choosing the raw materials (nodule, block, plaque), continuing with the production operations (preparation of the core and separation of the knapping products) and finishing with the conclusive transformation of the supports through retouching but in the opposite order, starting from the final product, the microliths. This choice was made on the basis of the hypothesis that the form and the size of the microliths influence the support necessary to its production and in turn this specifically conditions the form and the size of the core. It is also necessary to take into account that these parameters also depend on the type and form of rough material available.

The comparison between the available lithic assemblages from a large number of surface scatters and the elements, resulting from knapping experiments, made the reconstruction of the production process of the microliths possible.

4. THE MICROLITHS

The fact that during the Early Mesolithic both the shape and the size of the microliths were mostly standardized, unlike those of the tools, is underlined in publications on this topic. The corresponding lithic spectrum is distinguished by points, segments, triangles, backed points and backed bladelets that therefore represent the principal retouched forms (Broglio & Kozłowski 1983).

The pronounced size standardization is explained by M. Lanzinger as being due to their insert in hunting weapons. Lanzinger (1985) also hypothesises that "La complementarità delle singole armature microlitiche, che possono venire immanicate in numero diverso su una stessa asta o unità di tiro, giustifica la forte standardizzazione dimensionale di questi manufatti". The fact that most of these are not only small but are also very thin is remarkable. Their average size varies between 1.0 and 1.8 mm and rarely reaches 3.0 mm (Wierer 2008).

Bladelets or lamellar flakes were used for the microliths and the microburin technology was applied for the eventual elimination of the exceeding parts of the supports (too big, too thick or misshapen). With this method that was used for the first time in a systematic and exhaustive way during the Mesolithic (Broglio 1999) a secondary effect not to be underestimated, appeared. A robust and sharp point was formed on the workpiece that can be seen on a large number of microliths (Miolo & Peresani 2005). The real shaping came about later thanks to small abrupt retouches that have been removed in a unipolar mode starting from the ventral part of the blank.

4.1.1 Experimental modifications using retouches

To be able to understand and illustrate the information obtained from the abovementioned technological studies, the author has carried out shaping experiments aimed at creating microliths. Using a pointed pressure flaker made from deer antler, it was possible to retouch the support but only if it was very thin, maximum 2.5 mm.

During the experiment, the piece was placed, dorsal face down, on a hard support (in a central position or on a lateral edge). It is important that the piece in question is in perfect contact with the anvil at the exactly the point where the retouch will be detached because otherwise the piece will break. In this way large parts of the support can be detached quickly and without effort. It was possible to obtain the desired microlith from almost any shape of original laminar support.

This empiric data, obtained from various knapping tests, is confirmed by the analysis of artefacts found in archaeological excavations. Regarding the frequent repetition of modifications to the knapping products to obtain the microliths required, M. Lanzinger affirms that "... per la morfologia del supporto che è indifferente rispetto alla forma della armatura, nel senso che la stessa morfologia può essere ottenuta da supporti diversi ...". This means that the same microlith could be made from different supports (Lanzinger 1996). According to F. Fontana (2008) " It can be therefore affirmed that the production of lowly standardized blanks (by adoption of "pragmatic" reduction sequences) is balanced by the activity invested in their transformation into a more or less wide range of standardized microliths". Finally U.Wierer (2008) sustains that "As to what concerns the question on which blanks were used for producing backed tools, the implements themselves do not give sufficient information for an answer. In general, the original blank-morphology has been completely modified by retouch. For this reason, certain data, for example blade index, which is quite high, do not necessarily reflect characters of original blanks". Therefore all three authors agree that an ample transformation of supports came about during the Early Mesolithic.

4.1.2. Experimental modifications using microburin technology

It was often necessary to break the support. In this case, the same work method as that shown in 4.1.1 (that is the blank was always placed on the hard anvil with its dorsal surface downwards) was used but it was held diagonally (at about 45°) on the edge of the anvil and then it was incised with the removal of minute flakes to form a notch on the projected point (Miolo & Peresani 2005). The characteristics of these flakes, that are the concoidal fracture, the bulb and the shock waves, are created with the action

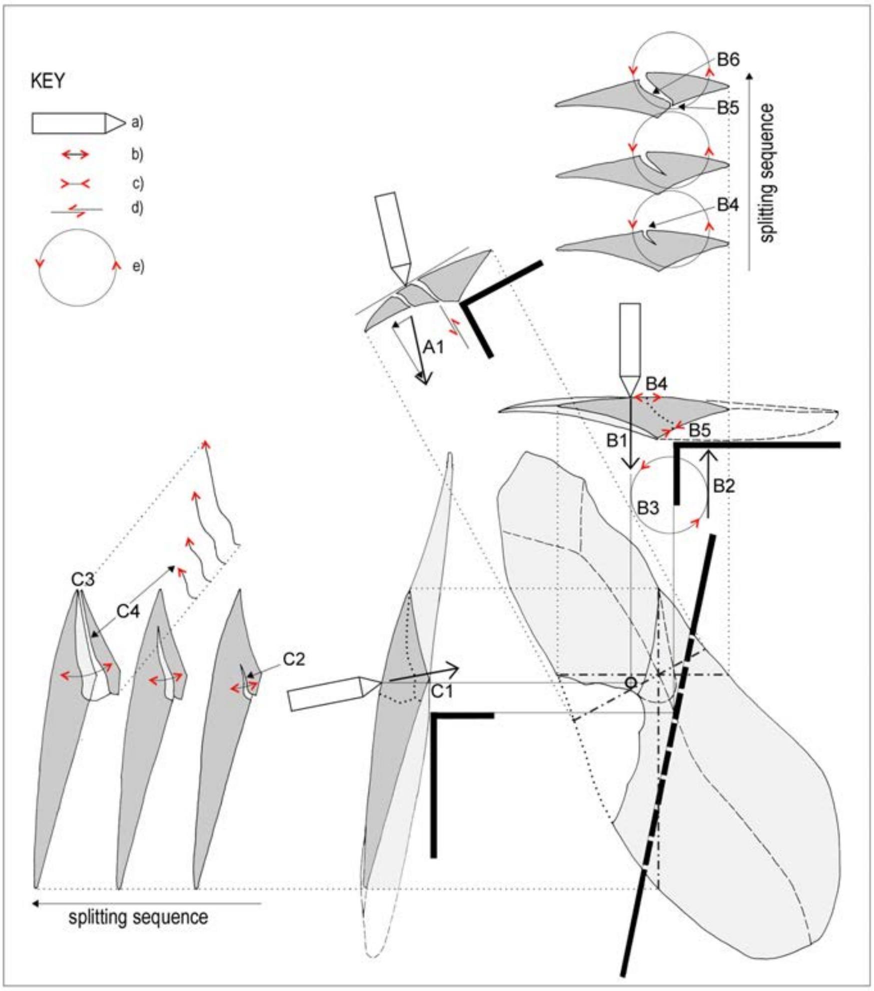

Fig. 2 - Removal sequence of the microburin Legend: a) pressure flaker, b) traction, c) pressure, d) shearing, e) rotations moment.
Fig. 2 - Sequenze di stacco del microbulino. Legenda: a) ritoccatore, b) trazione, c) compressione, d) tranciatura, e) momento torcente.

of the horizontal (traction) and the vertical (shearing from pressure and counter pressure) components of the force used (Fig. 2.A1) (Cotterell & Kamminga 1987), and correspond exactly to the stigma found on the archaeological flakes, blades and bladelets (Kerkhof & Müller-Beck 1969).

The working of the piece can be continued until the central axis of the pressure force gets to the dorsal ridge of the artefact (Fig. 2.C1). Further pressure leads to the removal of the whole part of the unsupported piece that is the so-called microburin. The removal surface is almost parallel to the edge of the anvil (Miolo 2002-2003).

The removal of the microburin, provocated by the force of the pressure flaker, starts from the deepest point of the notch between the central axis of the loading (Fig. 2.B.1) and the anvil's counter pressure point (Fig. 2.B2).

These two forces (Fig 2.B1 and 2.B2) cause a rotations moment (Fig. 2.B3) made up of the traction force that starts the fracture (Fig. 2.B4) and the compression force that articulates in the removal rotation point (Fig. 2.B5). Following the energy progression of the rotations moment and also/the properties of the flint fracture, finally a rounded removal surface characterised by a bilateral end part shaped like an "S" is formed (Fig. 2.B6). One of these counter curves distinguish the beginning of the fracture, while the other forms the removal rotation point.

The splitting off takes place perpendicularly to the rounded removal surface and is caused by the eccentric stress of the rotation with the centre of the rotation being on the pointed end of the removal surface on the border of the support (Fig. 2.C3). A more or less evident depression forms at the start of the fracture (this must not be confused with a bulb negative!) and is conditioned by the tensile force (Fig. 2.C2, Fig. 4.A.a). The development of the removal surface continues with a slightly rounded movement (Fig. 2.C4) with an counter curve on the edge of the depression that finishes at the rotation point situated on the margin of the support (Fig. 2.C3).

These curves, along and transverse to the splitting off, show the unmistakable saddle-shaped relief on the surface of the microburin. This saddle is in the longitudinal direction usually slightly convex and transversally concave (Fig. 4A.b).

For this reason, it is interesting to note how the flint reacts to the effects of traction, pressure, rotations moment and shearing:

- when only a traction force is applied to the detached piece a concave removal surface, recognisable by the above mentioned small depression, is formed (Fig. 3.1, Fig. 4A.a). There is also an "S"- shaped concave curve at the beginning of the splitting off (Fig. 3.2).
- a combination of traction and shearing (result of compression stress and counter compression stress) develops the so-called bulb, recognisable on the flakes detached during the creation of the notch (Fig. 3.3).
- a combination of compression and rotations moment develops a convex removal recognisable at the rotation point at the end of the "S"- shaped splitting off (Fig. 3.4).

4.1.3. *The microburin and the semi-finished product with "piquant-triédre"*

Both a part of the retouching used to form the notch and a genuine concave removal surface remain on the "waste-product", the microburin. The support made for further work is however characterised by the remaining part of the retouching and a convex removal surface, the "piquant-triédre", as a correspondent to the microburin. This surface forms, together with the ventral and dorsal side of the artefact, a sharp tip with a robust triangular section that is resistant to torsion and flexion in all directions. The proof of this can be found, whole or partially further retouched, on many microliths. (Fig. 4B)

These experiments show that the microburin technique distinguishes itself from simple retouching in the vital importance of the positioning of the piece diagonally on the anvil while the pressure of the pressure-flaker is always constant. Both work processes that is the shaping by retouching and the microburin technique, can be seen as unitary and closed work cycles but only if the laminar support is very thin.

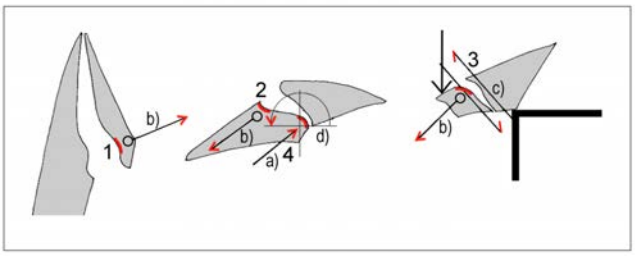

Fig. 3 - Definition of the formal appearance of fractures after: a) pressure, b) traction, c) shearing, d) rotations moment, d) fracture sequence.

Fig. 3 - Definizione della forma delle fratture in conseguenza a: a) compressione, b) trazione, c) tranciatura, d) momento torcente, d) andamento della frattura.

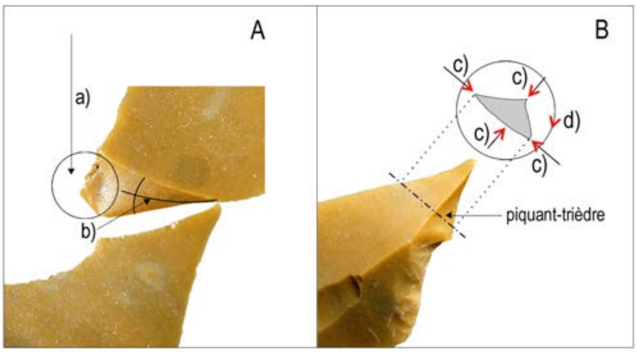

Fig. 4 - The microburin and the semi-finished product with „piquant-triédre". 4A: a) fracture induced by tension b) S-shaped surface. 4B: c) bending resistence, d) torsion resistence.

Fig. 4 - Il microbulino ed il semilavorato con „piquant-triédre". 4A: a) frattura azionata dalla trazione, b) superficie a forma di sella. 4B: b) resistenza alla flessione, c) resistenza alla torsione.

The shaping of the notch, obtained by using a pressure-flaker, does not create problems up to a thickness of 2mm but it requires much more force for thickness up to 2.5mm and is almost impossible to work when over 3mm. These values are confirmed by the analysis carried out on microburins by R. Miolo. The average thickness of the microburins from the "Casera Lissandra 17" excavation always measured up to breaking point is 1.6 mm (Miolo 2002-2003).

5. THE SEMI FINISHED SUPPORTS (THE KNAPPING PRODUCTS)

As was said before, the support necessary for the fashioning of the microliths must be thin while its shape is of secondary importance. The knapping products used to produce tools such as end scrapers, burins, retouched blades etc. can be much thicker and larger. Normally these elements are over 25 mm long (Lanzinger 1985).

A lithic assemblage coming from two open-air sites identified by the Author is presented to enable an in-depth comparison between the different characteristics of the lithic function (Kompatscher & Hrozny Kompatscher 2007).

5.1. The knapping products of the open-air site "SA5B" identified as a hunting camp and of "PJN4" identified as a base camp

Through an analysis of the inventory of the hunting camp (marked in the inventory as "SA5B", Fig.1) where the microliths were predominant it is verified if the knapping products have specific characteristics and if these are the result of specific work techniques. This inspection is carried out by a dimensional valuation and an analysis of the characteristics and the peculiarities of the semi finished products. A further analysis, based on a comparison between these artefacts and those of another site considered as a base camp (marked in the inventory as "PJN 4", Fig 1), was carried out on the possibility that the production processes have different technological characteristics or if there are only differences in size. The Author has visited these two sites periodically in the last 15 years and both of them are characterised by an abundant lithic inventory distributed over a restricted area (about 15 or 10 m^2).

Before presenting these sites, chosen as being characteristic of most of the high mountain sites with open-air/ findings, it is necessary to note that how the single assemblages were created is often no longer readable (the result of one or more dwelling periods during a chronological period). The only way to analyse the lithic industry of these sites is to compare them to sites that have been excavated and dated. This means that the archaeological evidence but also the typological research carried out in Alto Adige and in the bordering region, in the Trentino, can be used as terms of comparison (Bagoloni & Dalmeri 1987, Dalmeri & Lanzinger 1992, Lanzinger 1985)In this sense the inventory of the Mesolithic settlement "SA 5B", considered a hunting camp, promises well for a typo-technological analysis. It is situated on the central part of a crest and dominates the "Cresta del Alpe di Siusi" at 2230m. a.s.l. Microliths and very small knapping products (average weight 0.12 grams/ piece) predominate in this rich lithic inventory. On the basis of the characteristics and the composition similar to the inventory of the site "SA XV" situated nearby and excavated in 1985, the site "SA 5B" can be dated to the Middle Sauveterrian (Lanzinger 1985).

In order to compare the lithic characteristics of this site to those of a base camp, the site "PJN 4",located on the north side of "Passo Pennes" in a wide basin at 1990m. a.s.l. was selected. This site is characterized by a balanced relationship between microliths and tools, and also by the presence of much larger knapping products (average weight 0.57 gram/ piece). Unfortunately the lithic spectrum only allows a general dating to the Early Mesolithic. However it contained typical lithic compositions that are valid for the majority of the Mesolithic sites in the geographical area under investigation.

The inventory of the site "SA 5B" of 1187 artefacts includes 30 microliths and 7 tools. The functional character as a hunting camp is even more underlined by the high number of microlith fragments. However the relationship at site "PJN 4" is of 7 to 8 out of a total of 382 artefacts (Tab. 1).

A radiometric measurement was not possible for either site as there were no hearths with carbon remains.

5.1.1. The characteristics of the knapping products in the two inventories

The knapping products from the hunting camp site "SA 5B" are not only small and very thin (Fig. 5) but also tend to have a regular profile and a triangular or a trapezoidal section as well as a small, smooth striking butt and a rounded proximal face while the percussion angle is acute (Tab 2).

The base camp "PJ N4" inventory is instead characterised by larger and thicker knapping products (Fig. 5) with an often-irregular profile and a deformed section. Their peculiarity is also in the presence of big striking butts, which are often natural and straight. The percussion angle is more open (Tab. 2).

In the difference seen in knapping products from the two sites, one can presume that the work method used to fashion the microliths distinguishes itself in both sites. This should be particularly evident in the respective shape and size of the cores (subject discussed in chapter 6.4).

Tab 1 - Number of tools and microliths on the sites SA 5B and PJN 4.
Tab 1 - Numero di frequenza di manufatti litici nei siti SA 5B e PJN 4.

	site SA5B	site PJN 4
Total number of lithic artefacts	1187	382
Tools	7	8
Baked tools	30	5
Microlith fragments	34	4
Microburins	53	15
Cores	2	3

Tab. 2 - Characteristics and relative percentage frequence of the blanks on the sites SA 5B e PJN 4.
Tab. 2 - Caratteristiche e relativa frequenza percentuale dei prodotti della scheggiatura nei siti SA 5B e PJN 4.

		site SA 5B	site PJN 4
Dimension	mean weight	0,12 gr.	0,57 gr.
Contour	parallel or convergent lateral borders	71,0%	53,0%
	irregular lateral borders	29,0%	47,0%
Cross-section	triangular, trapezoide	62,0%	46,0%
	shape-less	38,0%	54,0%
Platform remnant	straight	53,0%	77,0%
	rounded	47,0%	23,0%
Surface of platform remnant	primary (cortex ecc.)	37,0%	47,0%
	smooth	50,0%	32,0%
	facetted	13,0%	21,0%
Shape of platform remnant	punctiform	7,0%	11,0%
	linear	20,0%	7,0%
	crushed	22,0%	11,0%
	extensive	51,0%	71,0%
Flaking angel	mean angle	68,7°	80,3°

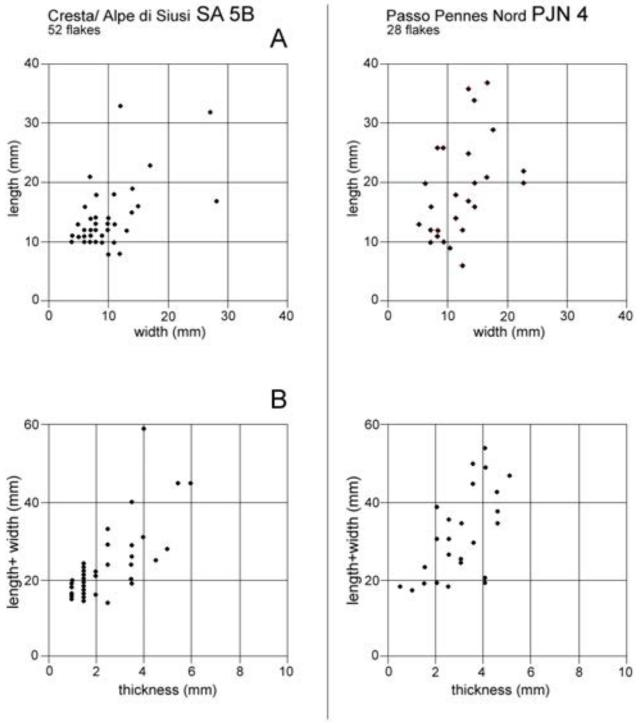

Fig. 5 - Scatter plots showing lenght, width and thikness of the entire flakes on the sites SA 5B e PJN 4.
Fig. 5 - Diagramma di dispersione delle variabili lunghezza, larghezza e spessore dei manufatti non ritoccati interi nei siti SA 5B e PJN 4.

5. 2. *Experimental fashioning of microlith supports and the relative considerations*

The results of the appropriate experiments, aimed at producing thin microlith supports using direct percussion and the following technological analysis are the basis for reflections on the characteristics required by both the removal surfaces of the cores and for the debitage techniques:

-perpendicular to the direction of the blow, the removal surface should be a little (never greatly) convex. As the radius of the curve becomes smaller, the thickness of the supports increases (Fig.6A). Starting to work from a edge of the core is without sense, as in the first work phase relatively thick products will be expected. This explains the rarity of crested blades in the high mountain inventories;

- the removal surface should only be sufficiently long so that the flakes or bladelets obtained are only slightly longer than the microliths desired. Small flakes and bladelets are clearly thinner than the larger ones, consequently the cores are also small and proportioned to the dimensions of microliths (Fig. 6B);

- the striking point of the percussor should be as near as possible to the edge of the striking platform. The bigger the distance, the thicker the knapping products (Fig. 6C).

6. THE CORES

During the Late Epigravettian in the south alpine area that preceded the Early Mesolithic, mostly nodules, blocks and some flakes were used to fashion the cores used as supports for the microliths. In the case of nodules the removal sequence started from a narrow side whereas with the blocks it started from an edge and with the flakes from one of the two lateral borders (Montoya 2008).

However during the Early Mesolithic, a fundamental change in the work techniques used to fashion microliths began to appear: removal starting from the larger side of the core becomes the norm.

An Early Mesolithic core, fashioned from a flake during the initial work phase (Num. Inventory “SA 58.1”, provenance: Cresta di Siusi Schneid, raw material: quartz) can be seen as an example of the fact that the dimensional reduction of the microliths also changed the flaking technique:

In fact the microlith support is not removed from the lateral border of the flake as is reported for the Late Epigravettian but rather from a face of the support (in this case the ventral face). The slightly curved *débitage* surface allows the realisation of very thin supports, which contrarily to the Late Epigravettian larger and straigther bladelets, were a little wider (Fig. 7).

6. 1. *Core size*

The Author had 70 open-air findings for the research on the cores at his disposal. (Tab. 3). 19 of these are oval with an average diameter of 22.8 mm and an average thickness of 12.6 mm. The remaining 51 cores have prismatic forms, conical or banded with an average length of 23.9

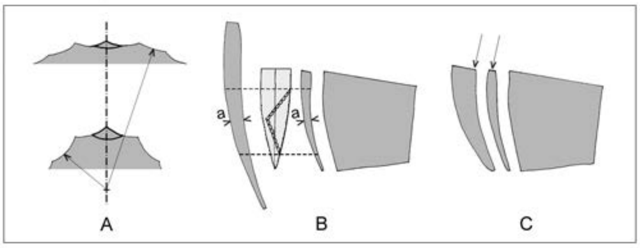

Fig. 6 - Characteristics required from cores and the flaking surfaces.
Fig. 6 - Caratteristiche richieste ai noduli e alle superficie di débitage.

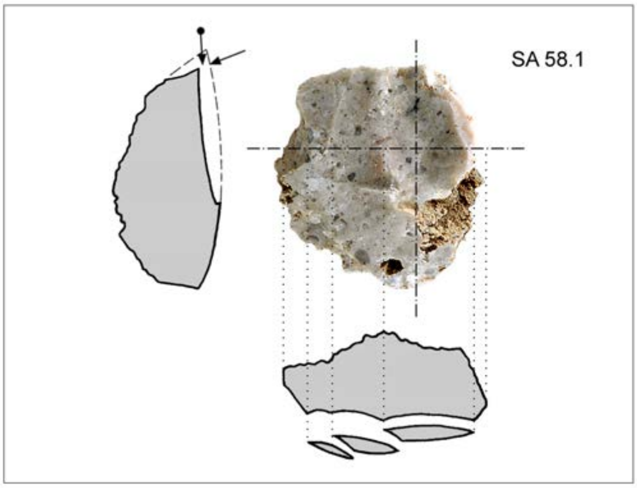

Fig. 7 - Core „SA 58. 1“ - beginning of the exploitation (scale 1:1).
Fig. 7 - Nucleo „SA 58. 1“ - *inizio dello sfruttamento (scala 1:1).*

mm, an average width of 22.1 mm and a depth of 15.6mm. All these cores have been fashioned from small blocks, nodule parts, flakes or plaques.

From the point of view of size, they are visibly small: the longest respective removal negatives on all the removal surfaces show that before leaving the cores, the last flakes or bladelets can only be used as microliths (Fig. 8).

It is documented that a certain number of cores are not only small because of the consequences of the advanced removal of the flakes but also because the lithic supports were already very small. For example, the core “AJ 18.01” could be mentioned. Initially it was entirely restricted by natural faces and then only one side was used. As a result, the size of the lithic support could not exceed 21/18/22 mm (Fig. 9).

6.2 Subdivision of cores according to the shape of the raw material

The lithic material used to fashion cores suitable for the production of microlith supports consisted in thick flakes, nodules, blocks or plaques. It is only possible to partially document the original shape of the cores examined as before being abandoned they were often reworked (changes in the removal direction, use of different striking platforms and *débitage* surfaces). The lithic industry assemblages analysed included 70 cores of which:

1) Cores on flakes

17 elements still show traces of the ventral face of the original flake. The presumed base products of 19 oval cores with 2 opposite striking platforms are flakes and in part, plaques. This definition is based on the relative research carried out by A. Broglio & J. Kozłowsky (Broglio & Kozłowsky 1983).

Tab. 3 - List and characteristics of the analysed cores.
Tab. 3 - Elenco e caratteristiche dei nuclei analizzati.

type	quantity	striking platform	flaking surface	annotations - flaking surface	dimensions of cores			cores shown
	70				min.	mean	max.	
A1	19	-	2		16/15/07	22,6/22,9/12,6	33/39/34	AJ 01.43
A2	7	-	2		14/16/11	25,8/22,6/14,3	33/34/18	BB 09.02
B1	13	1	1	straight to semicircular	16/15/09	23,7/24,8/13,2	36/40/22	BR 01.45,JO 12.02
B2	7	1	1	circuiting (in part)	10/16/13	16,7/21,4/20,8	31/29/29	RJ 70,GJ 11.01
B3	1	1+1	2	two opposite flaking surfaces		34,0/27,0/14,0		SA 5A 09
B4	6	2	1	bipolar *dèbitage*	19/13/10	23,6/15,7/11,3	26/18/14	PJN 04.03
B5	4	2	2	two opposite flaking surfaces	28/16/11	30,7/22,5/16,5	34/27/24	PL 01.01
B6	4	2	2	two opposite flaking surfaces one of these bipolar	17/09/04	21,0/15,7/11,7	24/20/19	RJ 130
B7	1	2	2	two opposite flaking surfaces both bipolar		21,0/32,0/11,0		MP XX
B8	2	2	1	*dèbitage* from two directions (core turned 90°)	17/20/17	22,5/26,0/18,0	28/32/19	WE 07.01
B9	1	2	2	two opposite flaking surfaces (core turned 90°)		24,0/23,0/11,0		SA 15.08
B10-B12	4	3-6		*dèbitage* from 3 to 6 flaking surfaces	19/13/10	22,5/17,3/18,7	26/22/38	SA 27.02,PJN 04.07,JT 60
B13	1	?	?	no suitable flaking surface		32,0/30,0/22,0		

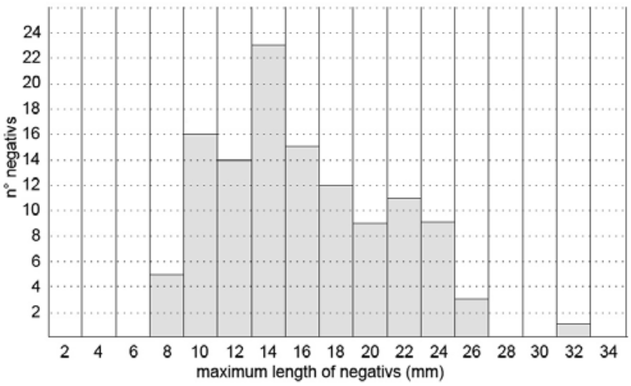

Fig. 8 - Maximum length of the scars on the several flaking surfaces.
Fig. 8 - Lunghezza massima dei negativi sui singoli superficie di débitage.

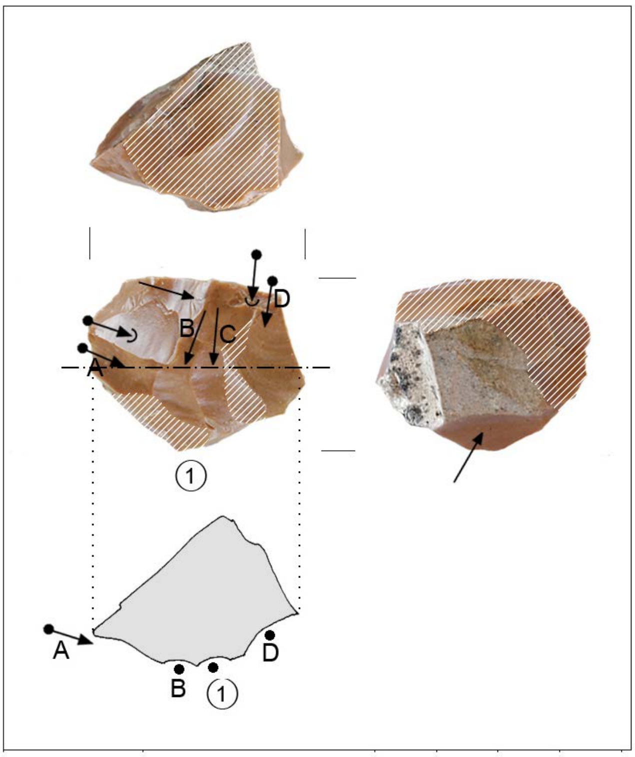

Fig. 9 - Core „AJ 18.01“ for key see fig. 10 (scale 1:1).
Fig. 9 - Nucleo „AJ 18.01“ legenda vedi Fig. 10 (scala 1:1).

2) Cores on plaques

Plaques were used as the raw material for the production of 4 cores.

3) Other cores

Of the remaining 30 cores, the majority was associated to blocks or nodules but it cannot be excluded that a certain number came from flakes and plaques

The following percentages of the single core supports come from this subdivision:

- flakes ca 50-60%
- nodules and blocks ca 30-40%
- plaques ca 5-10%

Therefore it can be presumed that in the high mountains, microliths were mostly made with cores coming from flakes.

6. 3. Subdivision of cores according to the striking platforms and the débitage surfaces

The operative techniques, applied for the production and the use of the cores presented here, have been organised according to their striking platforms and removal surfaces.

For this reason, the cores have been subdivided into 2 groups and precisely into a group “A” that contains the cores that do not have a specific striking platform as such but where a second adjacent *débitage* surface has been used instead; these cores are also characterised by acute flaking angles (50° - 75°). The second group “B” contains specific striking platforms and wider flaking angles (65° - 95°).

6. 3. 1. Group “A” cores „without“ striking platforms

26 of the 70 cores, that make up 37%, have 2 adjacent removal surfaces. The splitting off of the flakes and the bladelets started from the edge where the two removal surfaces met. In this case, the surface behind the one chosen for the splitting off acted as the striking platform (An alternate systematic use of the 2 *débitage* faces during the work was not verified.)

1) Group “A1” - oval cores

The 19 oval cores represent the majority of group “A” and may have been made only from regular and quite large supports such as, for example, from rough flakes. Differently from all the other cores examined, the oval ones result from a systematic, programmed process. The two convex *débitage* surfaces form, in a more or less lengthy tract, a common edge. The bilateral work cycle starts there and it is almost always radial and only rarely in a single direction. The size of the removal negatives found on this type of core suggests that they were used exclusively for making microliths and that they have been shaped precisely for this purpose (Fig.10, A1).

2) Group “A2” - conical cores

In the case of the remaining 7 cores, the two *débitage* surfaces form a common edge only in a limited part of the support and it is that part that is utilized. Also in this case, the flaking angle is acute and the striking edge is frequently rounded (Fig.10, A2).

6. 3. 2. Experimental preparation and management of a Group “A1” core

A flattened core was created from a thick flake together with the removal of the concave faced pieces. The core was more or less discoid and slightly curved on both sides from which small flakes and bladelets could be taken for microlith supports. Therefore this type of core allowed an optimal utilization of the raw material seeing as how it gave the following opportunities:

- the débitage can be either radial or occasionally with parallel bilateral removals, in this way removing all the outside of the core until dimensional exhaustion is reached;

- the removal of the products can start from both sides with the possibility of choosing different parts of the edge. This shows that during the process the areas of the core that offered the best *débitage* conditions could be used;
- the two slightly convex surfaces allowed the creation of very thin supports;
- the acute striking angle leads to the formation of a little developed bulb on the artefact, an advantageous characteristic for the production of microliths both using the microburin technique and with retouching;
- finally the knapping products obtained are more regular and often have a triangular section that is perfect for microlith production.

6.3.3. *Group "B" cores "with" striking platforms*

A lot of evidence leads to the supposition that in the high mountains - far away from flint deposits - any available raw material was used and that in most cases the size and the irregular shape did not allow an economical and rational preparation. As a result, the use took place in a non-programmed (opportunistic) way based on the conditions in that moment and without a specific shaping out.

This fact has been observed in all the group "B" cores where except for the formation of a mostly straight striking platform, there has been no significant preparation carried out. The use of the natural striking platforms can be seen quite often, small corrections were also carried out on some elements. The fashioning of the sides, to create a better definition of the *débitage* surface can be seen only in 4 cases.

Of the total of 67 striking platforms of the 44 cores in group "B" analysed, 26 are smooth, 22 faceted (often previous *débitage* surfaces) and 19 had a natural striking platform. Of the 79 *débitage* surfaces, 40 are on the large side, only one on the narrow side (Fig.10, B1, JO 12.02), while 38 are no longer classifiable. In 36 out of 79 *débitage* surfaces the curve perpendicular to the direction of the removals on the abandoned cores shows a modest flexion, 24 have a sharp curve and it was not possible to define this characteristic in the remaining 19 examples.

On the basis of the presence of one striking platform and one *débitage* surface, 20 of the 44 group "B" cores show the beginning of the use of the raw materials available (cores "B1","B2"). The removal sequence continued until it was no longer possible to continue because of reflex fractures and lack of a suitable striking angle (Fig. 10, "B1","B2").

However, in the case of further use a necessary correction of the *débitage* surface was carried out by removing a large flake (Fontana & Cremona 2008) while there is no evidence of the removal of a tablet to correct the striking angle in any of the analysed inventories.

The reworking of a striking platform, specifically the use of a second *débitage* surface on the opposite side of the core, could be seen only in one of the 44 cores (Fig.11,"B3").

18 cores, in which the striking angle had become too obtuse were turned by 90° or 180° to find a new striking platform and were further used either on the original *débitage* surface or on a new one created on purpose ("B4" - "B9") (Fig.11, "B4", "B5", "B6", "B7", Fig.12 "B8", "B9"). A type of flake that often appears in the lithic inventories that has a triangular section and negatives on the current dorsal face perpendicular to the striking direction, indicates the re-use of the previous *débitage* surface after a 90° core rotation (Fontana 2008). Using a core found in the Pradestel Rockshelter (Num. 2343/L4) in the Val d'Adige (Bagolini & Broglio 1975, Dalmeri *et al*. 2008) on to which the Author managed to remount 10 flakes, one can try to explain this work procedure:

In a first phase, this core has been used on both opposite sides (Fig. 14, 1,2,3, and 1',2',3',4'). The flakes 2 and 3 have very thick proximal extremities and they become thinner towards the distal part, that is they finish by forming a point. With the removal of these two elements, the striking angle widens, preventing a further *débitage*. It can be presumed that because of the size (volume loss) a possible correction, using the removal of a tablet, was not carried out. Instead the core was turned 90° and re-used on the existing *débitage* surface. A flake with the above-mentioned characteristics shows work starting on the core that is orientated in the new direction (Fig. 14.4). After the removal of two further flakes, the core was abandoned (Fig. 14, 5,6).

All of this favours the hypothesis that in the Early Mesolithic, only marginal or secondary corrections were carried out on the débitage surfaces or striking platforms. Turning the cores was preferred. The 90° or 180° rotation could take place more than once until the core was dimensionally exhausted (Fig 12, "B10", "B11") as happened with 4 cores. The core "JT 60" (Fig. 13, "B12") must be mentioned as an example of repeated rotation as it was turned at least 6 times.

6.3.4. *Experimental preparation and management of a group "B" core*

The cores obtained from small blocks, parts of cores and flakes with a relative loss of volume did not require an accurate shaping as the supports sufficient for creating the microliths were small and their shape was of secondary importance. The author limited himself to a minimal preparation of the natural support: the creation of a striking platform and the formation of a suitable striking angle. A new striking platform was looked for when the *débitage* surface did not allow further use. This method was repeated again and again and so it can be treated as a non-programmed (opportunistic) action. The number of the elements used to make microliths obtained from the group "B" cores was very variable but on the whole, it never reached the high number obtained from the oval cores.

6.4. *Conclusions regarding the cores of the various lithic inventories*

In the Early Mesolithic, the hunter-gathers presumably carried 3 types of cores with them during their cyclic moves

- large cores for fashioning large flakes, blades and tools. These are totally missing from all the inventories analysed up til now and therefore can only be proved by the presence of final products and pro-

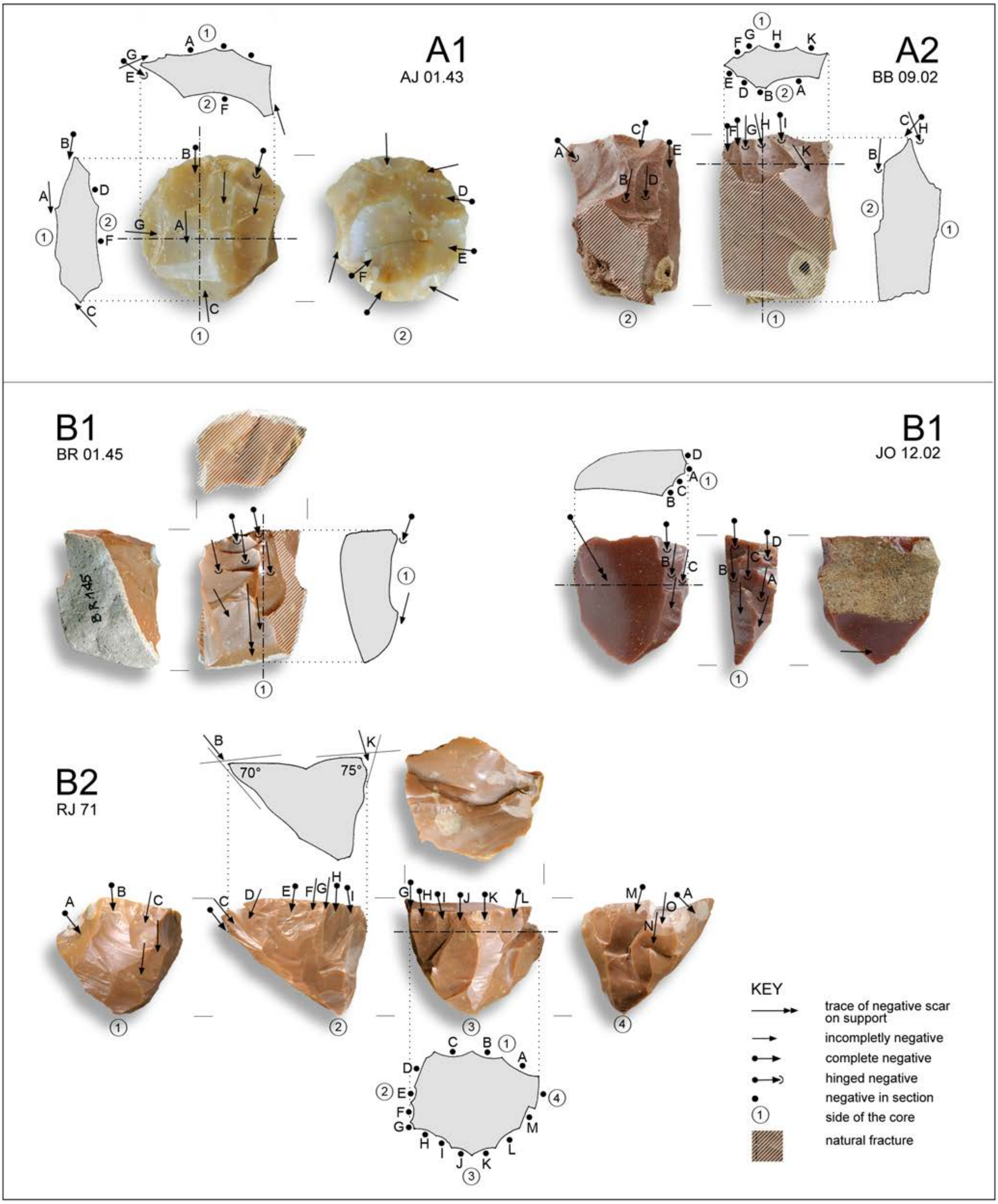

Fig. 10 - Representative cores of the groups „A1“,“A2“ e „B1“, „B2“ indicating the relative scars of *débitage* (scale 1:1).
Fig. 10 - Nuclei rappresentativi dei gruppi „A1“,“A2“ e „B1“, B2 con messa in evidenza dei relativi negativi di débitage (scala 1:1).

duction waste;
- oval cores with a systematic *débitage* used to make microliths (type “A1”); They are relatively frequent but it must be underlined that their shape suggests a specific lithic support such as a thick flake, a flat nodule or a plaque. These cores gave a large number of usable supports with little waste and were an efficient use of the raw material. It is also worth considering that the

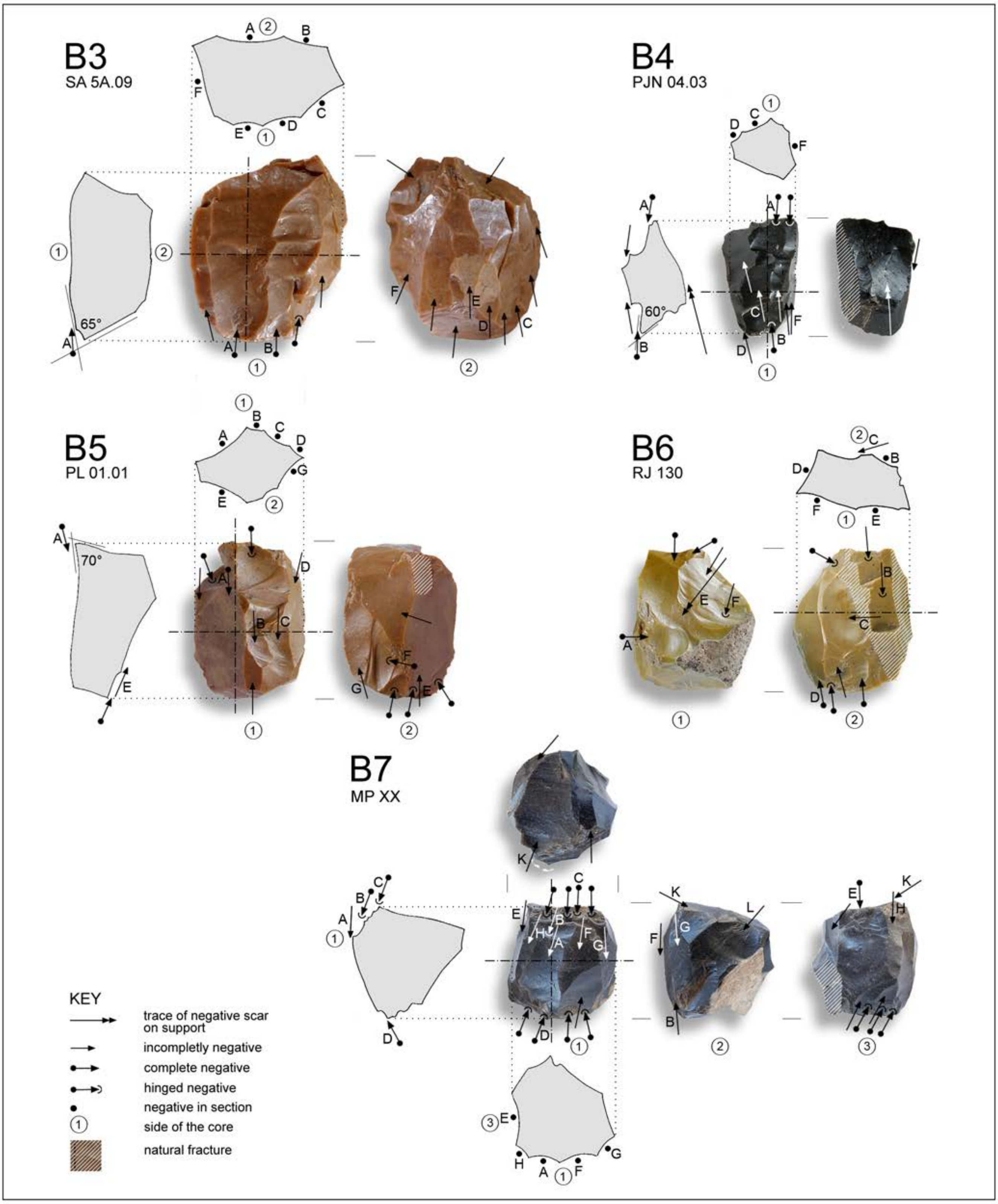

Fig. 11 - Representative cores of the groups „B3“ till „B7“ indicating the relative scars of *débitage* (scale 1:1).
Fig. 11 - Nuclei rappresentativi dei gruppi „B3“ fino a „B7“ con messa in evidenza dei relativi negativi di débitage (scala 1:1).

relationship between the weight of the cores that made up a large part of their equipment and the number of final products was important for the Mesolithic nomads;

- small elements like flakes, plaques, blocks and worn out cores for tools were gathered during the moves from one camp to another. These were mostly used in non-programmed (opportunistic) ways to create microliths.

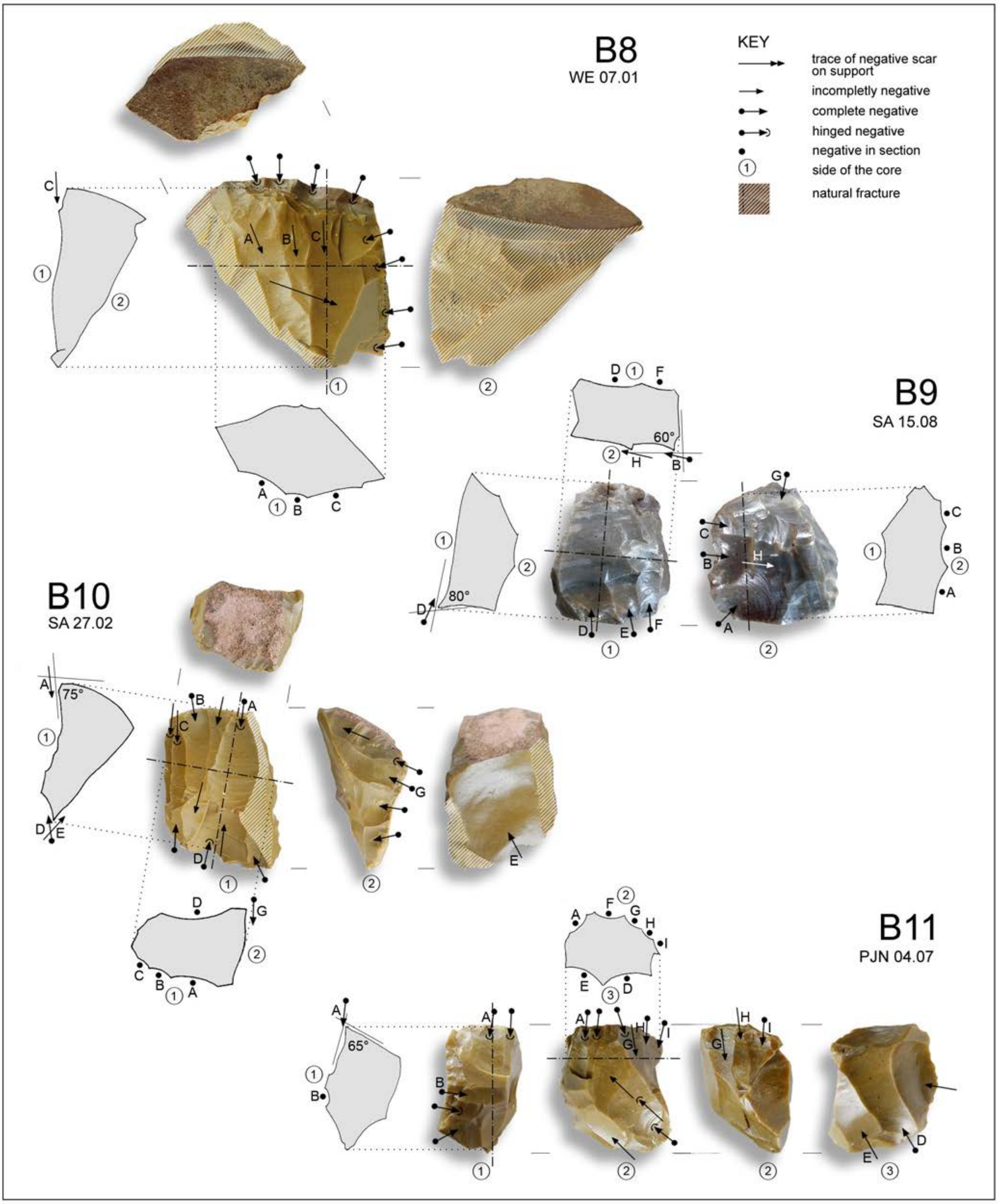

Fig. 12 - Representative cores of the groups „B8“ till „B11“ indicating the relative scars of *débitage* (scale 1:1).
Fig. 12 - Nuclei rappresentativi dei gruppi „B8“ fino a „B11“ con messa in evidenza dei relativi negativi di débitage (scala 1:1).

The study of the cores found in the two sites selected for this research show the following differences:

The inventory of site “SA 5B” includes two cores that belong to group “A” (1 core “A1” and 1 core “A2”). The respective knapping products are small and thin. They mostly have a regular profile and a trapezoidal or trian-

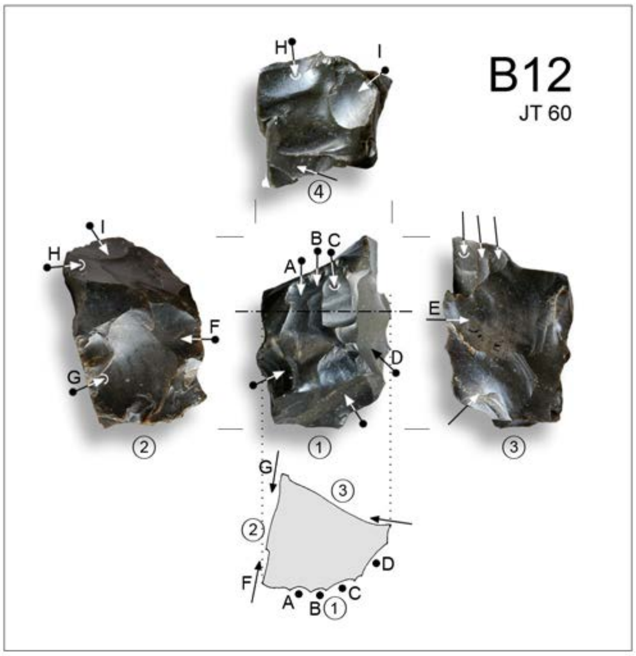

Fig. 13 - Core „B12“ indicating the relative scars of *débitage,* for the key see fig. 10 (scale 1:1).
Fig. 13 - Nucleo „B12“ con messa in evidenza dei relativi negativi di débitage, legenda vedi Fig. 10 (scala 1:1).

gular section. They are also characterised by small and smooth or collapsed butts and a rounded proximal extremity with an acute striking angle (Tab. 2). With this peculiarity, the knapping products also support the idea that the use of group “A” cores was preferable. (3 out of 4 of the cores also found in the hunting camps “SAXV” and “SAXVI” that are very near the site “SA5B” were of group “A”)(Lanzinger M. 1985). This tendency can be seen in the various hunting camp sites around the Colbricon Lakes where oval cores are prevalent: the quantity of these cores is about 45% on the Colibron site “8A” (US 4-5) and about 40% on the Colibron site 9 while at the base camp Colibron 1 the percentage is only about 20% (Bagolini & Dalmeri 1987).

The three cores from the base camp “PJN4” can be linked to group “B”. The knapping products in the lithic assemblage of this site mostly have irregular profiles and sections, large (natural o straight) striking platforms and a wider striking angle (Tab 2).

On comparing the raw material used for the cores with that used for fashioning tools and rough flakes, the idea that the cores could have been used first for the knapping products for the tools before being used for creating the microliths can be excluded on this site.

Even though the relative suitable cores are missing, thanks to the presence of small flakes and other waste products, there is the proof of the production in situ of part of the artefacts. (Moreover the import of the single preprepared elements is documented). So the conclusion is that the missing cores were not abandoned on the site but taken away and probably reused at the next rest stop.

6. THE MECHANICS OF THE FRACTURES AND THE RISPECTIVE TECHNOLOGICAL RESEARCH.

The work cycles for the production of the microliths have been studied on the basis of the following criteria:

1. The reconstruction of the flaking techniques and the operative sequences through an analysis of the retouched elements, the blanks and the cores, carried out on numerous artefacts found outcome from a large number of surface scatters. This research has also been facilitated by the refittings carried out on the artefacts themselves.
2. Experimental knapping and the technological deductions about the various techniques used.
3. Data on the mechanics of the fractures gained from the observation of the correlation between the various forces used and the behaviour of the fractures in the raw materials (These considerations have only been made exhaustively in the case of microburin production). This kind of analysis could be extended to all the characteristics of knapping products resulting from the different forces used and two of these characteristics that are often found on artefacts, can be proposed as examples:

- The lip, recognisable on the ventral face of the artefact that is generally defined as a consequence of a blow from a soft percussor. This peculiarity is always explained with empiric values (Pelegrin 2000). From the point of view of fracture mechanics, this curve is born from traction applied at the beginning of a “slow” removal that is characterised by a rotation. This traction force is the same as that seen in the removal of the microburins illustrated in figure 3.2 in chapter 4.1.2.
- A hinge fracture, which is normally formed as the result of flaking techniques used on surfaces that are too flat. This characteristic that is seen as a knapping mistake, can also be explained with fracture mechanics. The force used in a punctiforme way on the percussion surface extends radially and consequently the vertical component of this force (pressure) decreases with the increase in distance (Fig. 15, 1.0) As soon as the pressure is no longer sufficient to cause an ulterior shearing, the fracture front curves towards the dorsal face of the blade/flake. This incurvature is caused by the horizontal component of the acting force (F). In relation to the center of rotation this stress cause a rotations moment (M = F x L) (Fig. 15, 2.0).
  The lever L decreases on getting nearer to the centre of rotation and as a result the rotations force increases and reaches its maximum value (a multiple of the initial one) at the fracture point (F1 = M/L1), (Fig. 15, 2.1, 2.2). This rotations stress together with the remaining shearing pressure, produces a rounded removal surface that often has the shape of a quarter of a circle that reaches as far as the dorsal face. An analogous fact related to microburin removal is illustrated in figure 3.4 in chapter 4.1.2.
  If the rotation is superior to a quarter of a circle, the fracture curves in the opposite direction (Fig. 15, 3.2). This counter curve is caused both by the energy left over from the rotation and the resistance of the

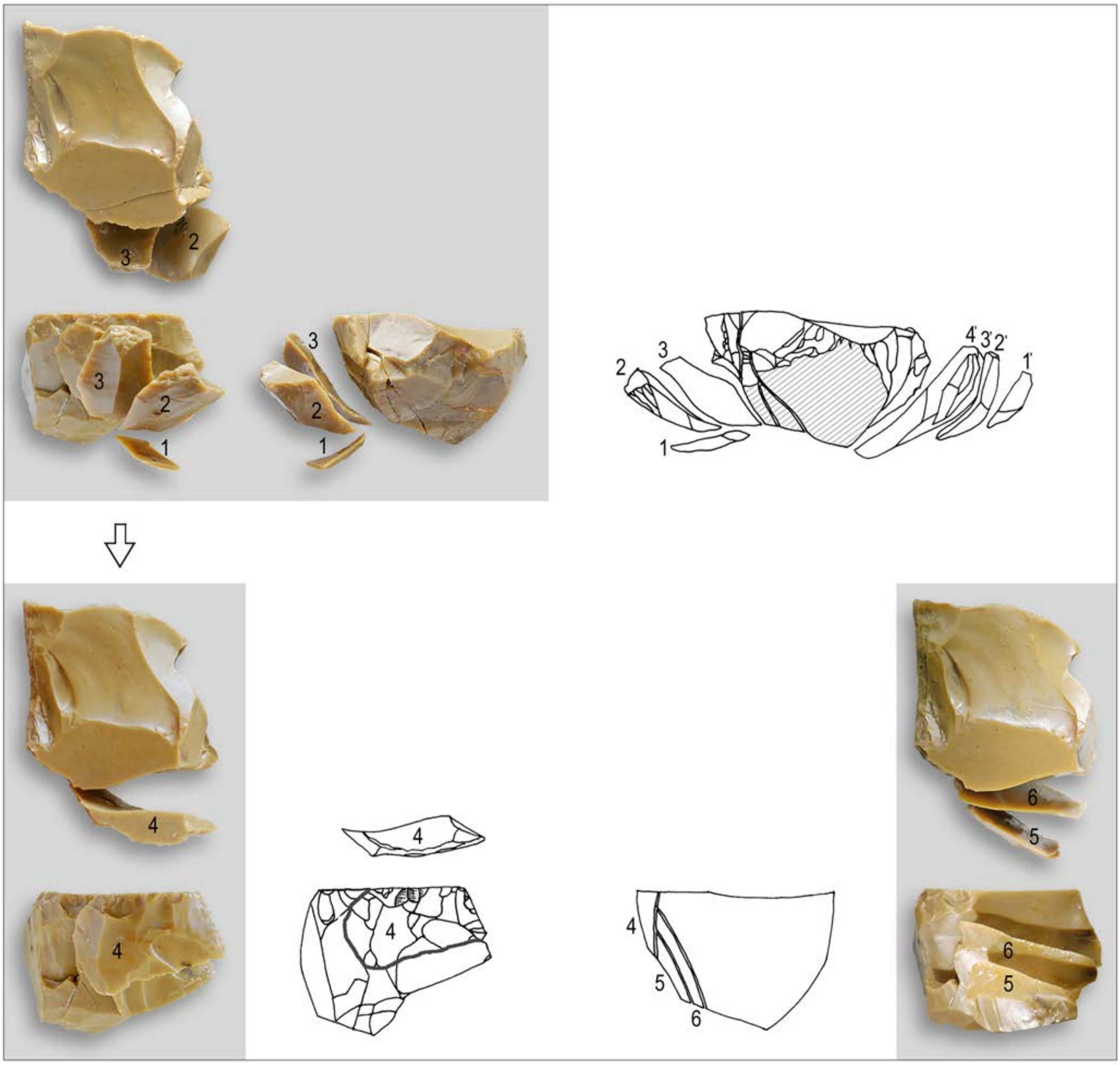

Fig. 14 - Core (2345/level L6) of Riparo Pradestel with refitted flakes and the three sequences of *débitage* (scale 1:1).
Fig. 14 - Nucleo (2345/livello L6) del Riparo Pradestel con schegge rimontate e le tre sequenze di débitage (scala 1:1).

surface situated between the hinged surface and the dorsal face (Fig.15, 3.1). Sometimes a wavy fracture surface forms presumably as the result of particular irregularities on the flaking surface or of a non homogeneous flint (Fig. 15, 4.3).

7. CONCLUSIONS

This research consisting in a technological analysis of archaeological artefacts and the relevant experimentation permits the identification of a fundamental evolution in the knapping techniques already existing at the beginning of the alpine Sauveterrian and the comprehension of the laws that regulate fracture mechanics by using as an example the microburin removal sequences.

Future research could be based on involving experts specialised in the field of fracture mechanics so as to be able to analyse the relationship between the applied force and the fracture movement. This would allow the acquisition of further elements to be used in the technological analysis of the entire prehistoric lithic industry.

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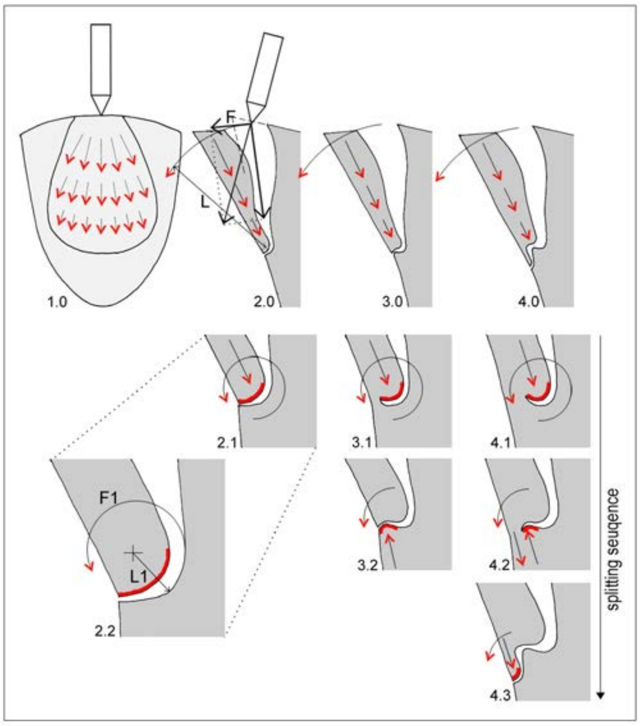

Fig. 15 - Splitting sequence of hinged flakes/bladelet: F. traction stress, L. distance between centre of rotation and traction stress , F1. maximum traction stress, L1. distance between centre of rotation and maximum traction stress.
Fig. 15 - Sequenza di sfaldatura di schegge/lamelle riflesse: F. forza di trazione, L. distanza fra punto di rotazione e forza di trazione, F1. forza massima di trazione (frattura riflessa), L1. Distanza fra punto di rotazione e forza massima di trazione.

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