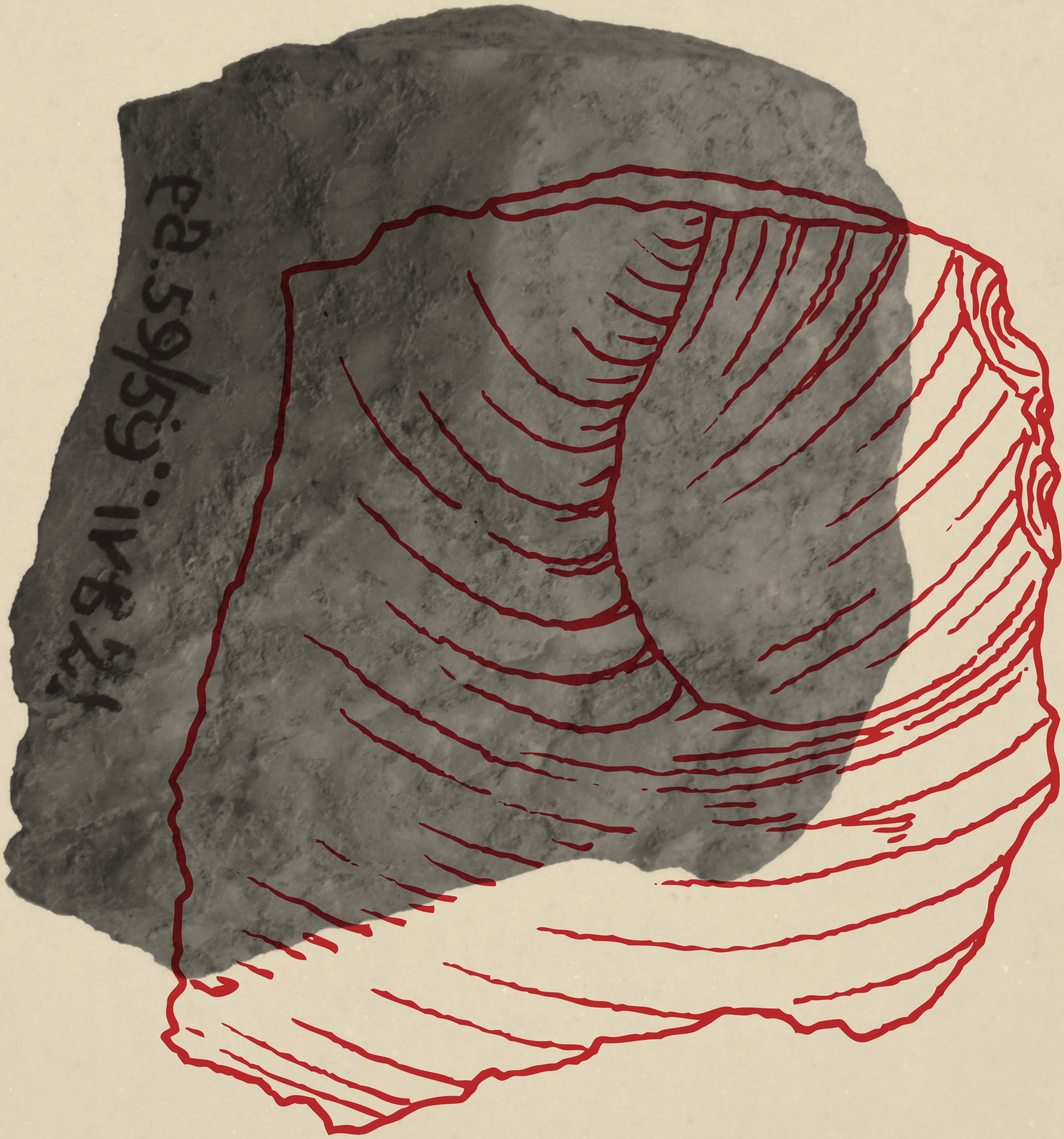
PARTITIONING THE PALAEOLITHIC

Introducing the bipolar toolkit concept



Jan Willem van der Drift

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Design and lay-out
Jelmar Geertsma
www.typehigh.nl

Frontpage
Flake from Dmanisi, the diffuse bulb and large bulbar scar result from te use of oblique bipolar flaking.

Aktieve Praktijk Archeologie Nederland
De Savornin Lohmanlaan 12 B
9722 HG Groningen
T: 050 526 50 61
W: www.apanarcheo.nl
E: postmaster@apanarcheo.nl
Postbanknr. 78.27.719 ten name van: APAN

Contents

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Abstract
In this article an addition is proposed to the partitioning system of the Palaeolithic. This addition consists of an independent development line, based upon the predominant use of bipolar reduction. This has been confirmed through experimental reproduction of the toolkit and study of the fracture characteristics. The bipolar development line is contemporary with Mode I, Mode II and Mode III. It is named the *bipolar toolkit concept.* The word 'concept' is chosen because the use of bipolar reduction influences the choice of raw material, the mental template of toolkit production and the preferred survival strategies.

Keywords: anvil, bipolar technique, bipolar toolkit concept, Clactonian, conchoidal flakes, diagnostic signs, oblique bipolar technique, Oldowan, Pebbletools, Tayacian.

1 Introduction

1.1 Three stages

The present partitioning system is based upon Stevens (1870). He distinguished between Palaeolithic finds from river terraces (the 'drift') and from caves. De Mortillet (1883) gave this partitioning a technical basis, by describing the 'cave' finds as Mousterian; characterized by *target flakes* intended for the production of points and scrapers. Abbé Breuil (1926) introduced the term *Levallois* (prepared core) technique and this became the identification mark that distinguished the Middle Palaeolithic ('cave' traditions) from the Lower Palaeolithic ('drift' traditions: the Clactonian and Acheulean). When we add the Upper Palaeolithic (Pleistocene modern man) this gives us the three stages of the most commonly used division of the European Palaeolithic. After the Oldowan was discovered, J. Desmond Clark (1977) proposed a new system with five consecutive development stages. The first stage, 'Mode I' consisted of cores and flakes (the Oldowan) whilst hand-axes appeared in 'Mode II' (the Acheulean). Clark had now effectively partitioned the Lower Palaeolithic into two development stages. The 'cave' Middle Palaeolithic with prepared cores became 'Mode III'. The Upper Palaeolithic based on blades and burins 'Mode IV'. And microliths were placed in 'Mode V'. It was a straight and simple staging system (see figure 1).

But towards the end of the 20th century, this simple system became challenged. Because when the dating techniques became improved, this showed that the stages were not at all chronological. The Clactonian for instance, had always been seen as a pre-hand-axe group, but now it was proven to be contemporary with the Acheulean. This contradicted all existing theories on technological evolutions. In an attempt to 'save' the system of successive stages, Roberts et al (1995) recommended that the differences between the Acheulean and Clactonian should be disregarded. Bosinski (1995) also suggested that in general there was no fundamental difference between industries with and without hand-axes. Furthermore sites like Bilzingsleben and Vértesszöllös became a problem for the successive staging. Such sites were dated into the 'Middle Palaeolithic' time-span but they missed the required Levallois technique. Therefore the Middle Palaeolithic was now redefined as: the era in which extinct hominids developed multi-cultural identities. The attempt to make the staging system work, made the system itself more important than the industries. Arguments were sought against the Clactonian and Tayacian industries. Finally even the complete prepared-core technical basis on which the very system was built was dropped. Therefore I believe it is correct to say that the current system of consecutive stages has failed.

1.2 The bipolar toolkit concept

The simple consecutive staging system failed because it classified industries without hand-axes as a 'lower stage of technical development' and consequently as a 'lower stage in the evolution of man', which of course meant these industries should have been outcompeted. The dilemma that they do exist has led mainstream archaeology to explain the sites as resulting from raw material shortage or other failures. Therefore the names of these industries should be abolished (Doronichev, 2008). In this paper I will show that the differences between non-Acheulean and Acheulean groups have a real and demonstrable reason; *the differences are based upon a completely different concept of the dynamics of striking flakes.*

The 19th century researchers already learned from the ethnographic record and through 'flint Jack' experiences that hand-axes and points and blades were all made by striking a core that is held in the free hand. Direct hard and direct soft (antler) percussion were the most common reduction techniques. Stevens (1870) did cite

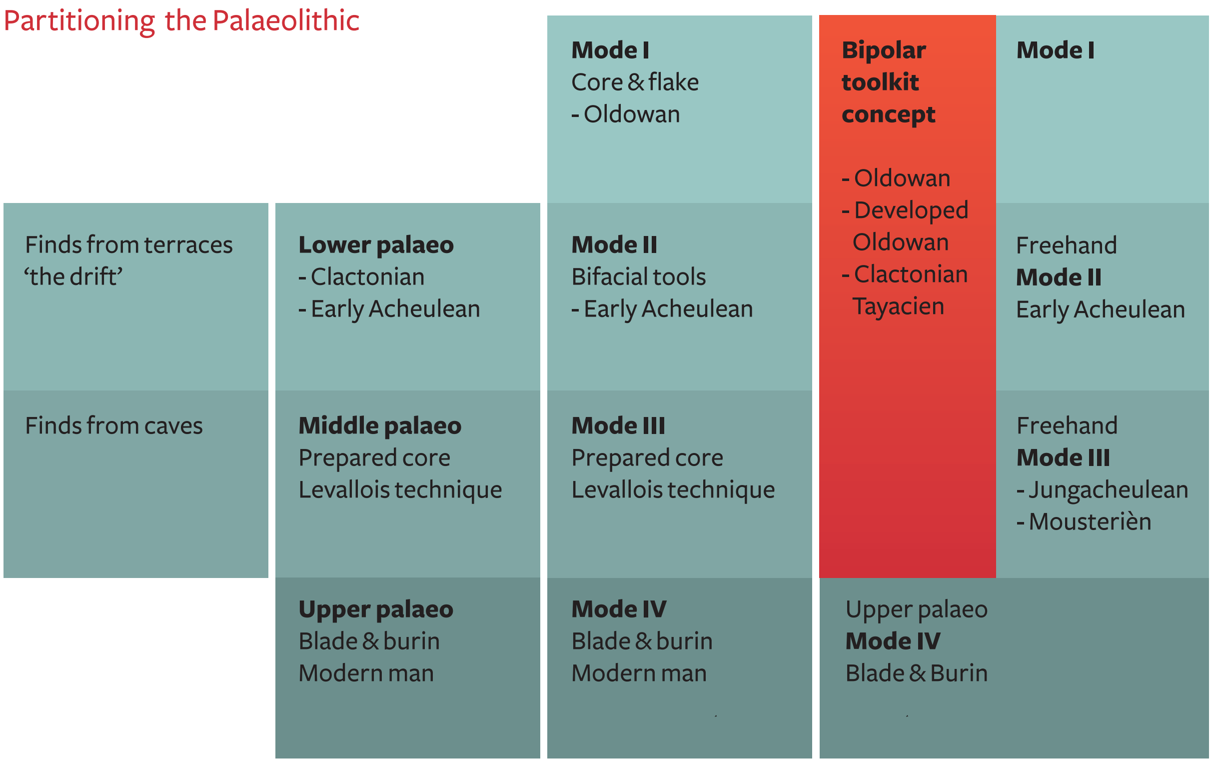


Figure 1: Partitioning systems for the Palaeolithic. Left column is based on Stevens (1870), the second column on Breuil (1926), the third column shows the staging system by Clark (1977). The system of consecutive stages failed as it was shown that many 'Mode I' industries were contemporary with the 'Middle Palaeolithic' time. A new partitioning system of the Palaeolithic is therefore needed. This new system is shown in the column on the right, where the non-Acheulean industries can find their correct place in the bipolar toolkit concept.

that the Shasta Indians used an anvil whilst making blades, but the real importance of anvil techniques has not been recognized until recently. It is a completely different concept of working stones. Instead of flaking a core from the free hand, the core was placed on either the ground or an anvil and cracked like a nut. This is called *'bipolar reduction'*, a name that was chosen because the forces simultaneously come from two opposed sides (hammer-side and anvil-side).

Archaeologists are now beginning to understand that rounded pebbles can only be broken with the support of an anvil (Prous et al, 2004). Breaking pebbles on an anvil produces pebble-segments instead of flakes. These pebble-segments seem rather clumsy, therefore bipolar reduction is considered a low prestige technique during Neolithic and Mesolithic times (Flenniken, 1979, Devriendt, 2008). All of this seems to confirm that bipolar reduction was merely an emergency measure, therefore there is little interest in the bipolar techniques from either prehistoric or experimental archaeology. In this paper I will however show the opposite to be true: bipolar reduction was a very successful basic technique for some Palaeolithic groups. In fact it was the only strategy that enabled groups to survive under climate conditions and in locations where the procurement of good quality raw material was insufficiently guaranteed. The reason is that under such conditions, hand-axe technology could not be passed on through the generations. In general it is fair to state that the non-Acheulean assemblages were based upon bipolar reduction as primary technique.

For these 'non-Acheulean' groups working on an anvil defined the basic way of thought (van der Drift, 1991). The dynamics of working on an anvil led to a reduction strategy that was very different from the bifacial Acheulean strategy. This defined the composition of the toolkit and it is important to note that it also defined the raw material strategy and the climatic preference (van der Drift, 2001, van Noort, 2010). So groups which used bipolar reduction had a very different mindset from the Acheulean groups. This implies we cannot continue to see Clactonian and Tayacian and pebbletool groups as merely a low-prestige-Acheulean. We must acknowledge these industries as a separate unit, I have named this the bipolar toolkit concept (van der Drift, 2007). The bipolar toolkit concept shows continuous presence during the Lower, Middle and Upper Pleistocene eras. It therefore represents an independent Palaeolithic line that developed in addition to the hand-axe traditions (figure 1).

2 Fracture types

We are all familiar with the diagnostic signs of conchoidal flaking (Schick and Toth, 1993) and therefore this paragraph and the next might seem redundant. But although we all have heard of the conchoidal flaking or CF signs, few have really studied these CF signs in great detail and even fewer understand the real reasons for the presence and absence of these signs and the implications this has for archaeology. So I must ask you for your patience and I must ask you to please return with me to the basics, explained in this and the next paragraph, in order to learn the correct interpretation of fracture types and diagnostic signs.

2.1 Conchoidal and non-conchoidal

Fractures are always the result of either an internal or an external force. Internal force ruptures are most often the result of repeated thermal expansion, the formation of ice or salt crystals can catalyse this process. The internal forces usually work centripetal-centrifugal or multidirectional. The main interest for archaeology lies in the unidirectional external force fractures. The relevant external force fracture types are
X: *fractures caused by a unidirectional force that is only counteracted by inertia* and
Y: *fractures caused by a unidirectional force that is counteracted by a blockage.*
Fracture type X can be reproduced in experiments by holding a core in your free and unsupported hand and hitting it with a hammer. The strike is counteracted only by the inertia of the core. That is why we call this technique: freehand reduction or freehand flaking. Fracture type Y can be reproduced in experiments by holding a core on an anvil and hitting this core with a hammer. The strike is counteracted by the blockage of the anvil. This leads to a compressive force inside the core starting from the hammer-contact-point directed towards the anvil-contact-point. The compression of course simultaneously works in the opposite direction; from the anvil-contact-point towards the hammer. In other words there are two opposed forces, that is why we call this technique bipolar reduction or bipolar percussion.

Regrettably the term bipolar is also used in the literature when type X fractures are made in opposed directions. For instance bidirectional blade cores (blades struck from the top towards distal end and after preparation of a new striking plane also in the opposite direction) are sometimes called bipolar cores. Certainly when real bipolar knapping is also described in the same article (i.e. Diez-Martin et al, 2010), terms like 'bifacial bipolar opposed' can be confusing. To avoid confusion in this paper, I will only use the term bipolar in reference to fractures caused by forces counteracted by blockage (Y type fractures).

Knapping experiments have shown that the fractures counteracted by inertia (type X, freehand flakes) are conchoidal. Experimental flint-knappers prefer to use freehand reduction and most archaeologists simply assume that Palaeolithic hominids also preferred freehand reduction. This assumption has led to the doctrine that artefacts should always show the diagnostic signs of conchoidal flaking. This has led to the common determination practice as shown in figure 2 algorithm A. When finds come from a coarse matrix or a disturbed site without hominid fossils, it is necessary to confirm they were made by hominids. If the finds show clear diagnostic signs of conchoidal flaking, they are considered man-made. If not, the finds are commonly classified as pseudo-artefacts. Knapping experiments have however shown that man-made fractures counteracted by blockage (type Y, bipolar flakes) are non-conchoidal. Prehistoric man-made bipolar fractures have been demonstrated in many archaeological sites (i.e. Cubuk, 1976, Franssen en Wouters, 1979a, Wouters et al, 1981, Prous et al, 2009, Diez-Martín et al, 2010, Mgeladze et al, 2011), so the assumption that only freehand reduction was used is long disproven. Therefore the doctrine that non-conchoidal flakes must be products of nature is false. This is confirmed by comparison of archaeological finds to experimental and industrial products (van der Drift, 2010b). This means algorithm A is incorrect and all conclusions based upon algorithm A must be carefully re-evaluated.

2.2 Algorithm B

The correct determination procedure is shown in algorithm B (in figure 2). The first important difference with algorithm A is that all finds from sites with fine grained and undisturbed layers (even when they include hominid fossils) should be determined with the same scrutiny as insecure finds. This makes secure sites with non-CF finds visible, confirming the use of bipolar reduction as basic reduction strategy in some sites. The frequent occurrence of non-conchoidal artefacts has not been recognized in the past because the conchoidal character of finds in secure sites was never questioned. In secure sites *it was simply noted that bulbs and scars were present, but this is not enough to distinguish between conchoidal and non-conchoidal fractures*. Non-CF

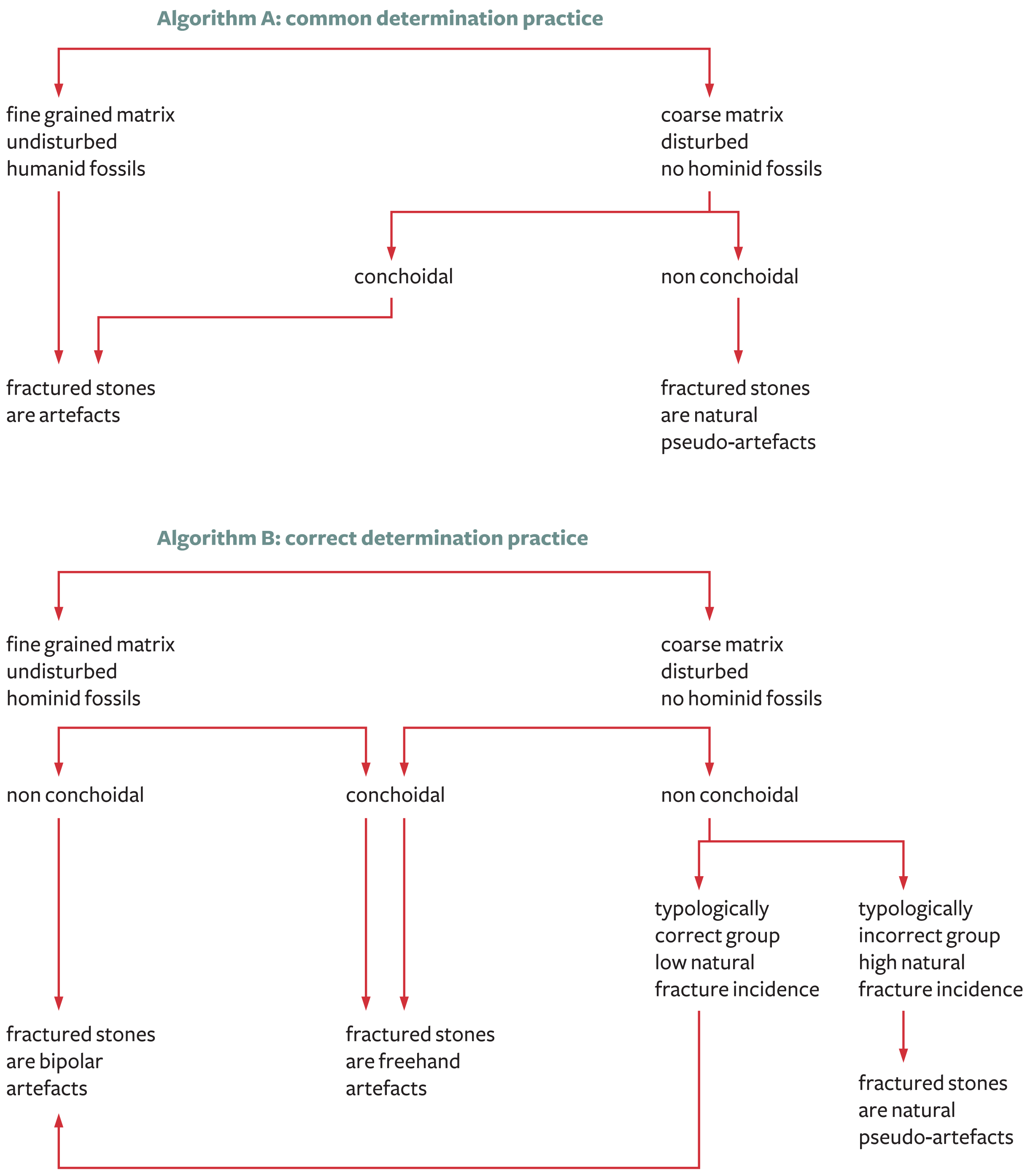


Figure 2: Determination algorithms of lithic industries. The commonly practiced algorithm A is based upon the misconception that all man-made lithics are conchoidal. When finds come from a coarse matrix or a disturbed site without hominid fossils, they are classified as pseudo-artefacts if they do not show the diagnostic signs of conchoidal flaking. But when we apply the same scrutiny on finds from an undisturbed fine-grained matrix with hominid fossils, it turns out that many of these sites do not have diagnostic signs of conchoidal flaking. So non-conchoidal artefact groups clearly exist. Therefore correct determination should be done as is shown in algorithm B. This procedure allows for non-conchoidal artefacts to be recognized in both secure and insecure sites.

finds can only be recognized by following the correct pattern-recognition procedure, based upon *strict interpretation* of the diagnostic signs as described by Stapert (1975) and explained here in paragraph 3. The correct use of algorithm B therefore leads to recognizing the bipolar toolkit concept as a major division within the Palaeolithic. Algorithm B also shows that the non-CF finds from less secure sites must be taken one step further, to see which are pseudo-artefacts and which are bipolar artefacts. It is highly probable that the finds are true artefacts if a *larger group* is found that is *in its totality typologically correct* and if this group comes from a site with a *low incidence of natural fractures.*

Imagine that we would have to build our perception of the Acheulean and Mousterian on only undisturbed fine grained secure sites with hominid fossils. As if none of the surface finds and disturbed or coarse-matrix handaxe sites existed. Then we would have little idea of the real importance of the Acheulean and Mousterian; this would completely destroy our concept of the large network. When we understand this it becomes clear what algorithm A did to our view of the bipolar industries. Algorithm A made it impossible to recognise the real nature of the Clactonian, Tayacian and pebbletool industry network, because the insecure sites were dismissed. This makes Vértesszöllös look like an incident based on poor raw material, instead of as part of a larger network of pebble-tool industries. Simply because insecure sites with the same toolkit (i.e. Jabeek, Maastricht, Valkenburg, Nagelbeek see Peeters et al, 1988a) are dismissed by algorithm A. But the finds (although they come from a course matrix) fulfil the requirements of forming large groups (tens of thousands artefacts) with a clear typology (exactly like Vérteszöllös) and the sites have a low incidence of fresh and unrolled natural fractures due to the low fall of the river Meuse. So algorithm B enables us to approve these finds and in doing so helps us to build a network of bipolar toolkit sites, creating a better perception of the Palaeolithic pebbletool groups.

3 Diagnostic signs

3.1 Bulbs and cones

Freehand fractures are only counteracted by inertia, so the fracture is caused by a directed force that comes from only one side. As a result the compression in a freehand fracture builds up in the shape of a cone (van der Drift, 2011). Physicists call this the 'neutral' cone (Bertouille, 1989) because you find compressive force inside this cone and just the opposite force (pulling-tension) outside of the cone. We can also call the cone 'idiomorphic' because the opening angle is determined by the properties of the stone itself; the opening angle of the cone is determined by the material and cannot be changed by the knapper (van der Drift, 1991). *The sharp contrast between compression inside the cone and tension areas outside the cone, leads to a large triangular shape, covering most of the ventral face of each flake*. This is illustrated in figure 3 on the left; the small drawing of a freehand flake clearly shows the triangular cone (red) contrasting with both side-areas (blue). On cross-section you can clearly see that the area inside this triangle protrudes. This bulging part of the fracture is a segment of the compression cone. During the fracture this cone is *pushed* downward by the hammer-strike. The inertia of the core keeps the (blue) areas to the left and to the right of the triangle in position as the (red) cone moves downward: this causes *pulling-stretching* tension. So these side-flaps break in a completely different way, leaving a depressed surface.

A bipolar fracture works completely different. There are two opposed forces, so perhaps you would expect two opposed compression cones. But against what you would expect, this cannot happen. The reason is that the area outside of the hammer-cone is compressed as well, by the second cone that would start out from the anvil-contact. There is just compression everywhere and a 'neutral' cone can only exist if the inside is compressed and the outside is stretched-pulled. In bipolar fractures there is at best only a small difference between more compression and less compression. The result is shown in figure 3 on the right. This type of bulb is commonly called a 'flat bulb' or 'diffuse bulb'. The word 'flat' is used as the opposite of 'prominent', a flat bulb should not be mistaken for a simple flat surface. Although a flat surface is possible in rare cases, the ventral face of bipolar fractures normally has a total curvature that resembles freehand fractures. Fractures that show 'diffuse' or 'flat' bulbs are *by definition* non-CF (Stapert, 1975). These non-CF fractures often show a very small prominent cone at the beginning of the flat bulb, this cone develops before the compression build-up is complete. Sometimes there is also a second dead-end cone which of course shows the same contrast.

The fracture signs were not inspected in most secure sites. Bilzingsleben is an exception, it was noted here that flat and unapparent cones dominated ('Flache und unscheinbare Kegel dominieren' Mania and Weber, 1986 p. 183). The fact that most finds showed diffuse bulbs clearly proves that the Bilzingsleben finds are non-CF. Nothing further was thought of this, it was not even consciously linked to the process Mania and Weber (1986) called shattering ('zertrümmern') because the researchers had no knowledge of the bipolar toolkit concept. This of course also prevented Mania and We-

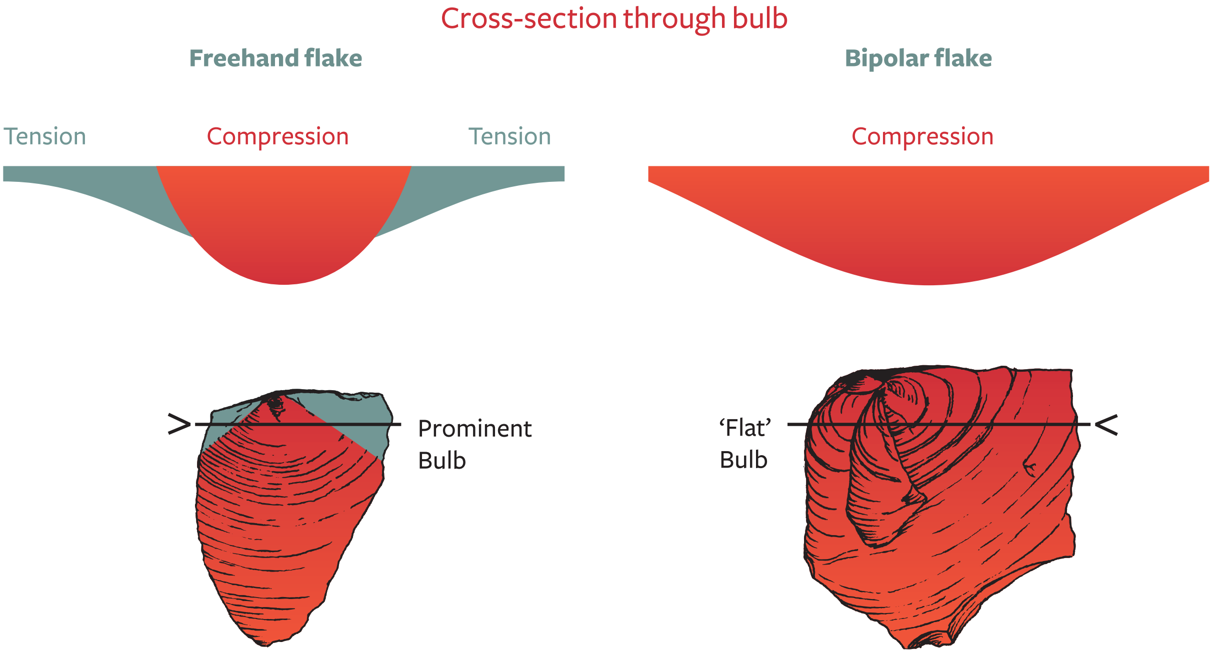


Figure 3: The compression (red) inside the neutral cone stands in contrast to the stretched (blue) zones outside the cone. This contrast causes the bulb in freehand flakes to be prominent. In bipolar flakes there are no stretching forces so there is no contrast. The absence of contrast in bipolar flakes leads to a type of bulb that is called 'diffuse' or 'flat'.

ber from recognizing that bipolar reduction implies a lot more than simple shattering and it kept them from recognizing that the bipolar reduction process determined the typology of the toolkit.

The drawings in figure 3 are based upon the flakes shown in figure 4. In figure 4 on the left you see the ventral face of a freehand flake (Acheulean from Persati) and on the right you see the ventral face of a bipolar flake (Oldowan from Dmanisi). I chose to compare these finds because both flakes are made from the same raw material (chert). Sadly however the comparison is still compromised because the Acheulean flake is a soft-hammer flake. The use of a soft hammer actually *reduces all contrast* (because the fracture is initiated over a wider oval area; Bertouille, 1989, van der Drift, 1991). To overcome this problem I have increased the contrast in figure 3, drawing the flake as if a hard-hammer was used. The fact that soft-hammers reduce contrast and thereby make the bulb less contrasting (in theory looking more like a bipolar bulb) demonstrates the complexity of the fracturing process. Some freehand flakes show less contrast than expected. And some bipolar bulbs actually show clear contrast, for instance when the floor is used as a soft anvil. A soft anvil produces less counteraction, therefore the result can sometimes completely mimic a freehand flake! The type of bulb shown in the Dmanisi flake in figure 4 is often seen in Clactonian assemblages. In that context it is often called a heavy bulb, because the diffuse curvature involves the complete surface.

3.2 Ripples

Ripples are believed to be *transversal* shock-waves (in French ondes de choque, Bertouille, 1989) progressing through the stone. But this is a complete misunderstanding. Light and sound travel as transversal waves, but a fracture (or rupture) is a very different process. A fracture is simply *one longitudinal front*, that tries to go straight through the core. This may surprise you because we clearly see ripples, to understand this we have to look closer at the actual process of rupturing which is a deformation phenomenon. Understanding deformation starts by trying to bend a thin glass object; it bends just a little but very soon the curvature already exceeds the maximal deformation glass can take. And it is right at this moment of exceeding the maximal deformation, that the glass breaks. You can deform glass by bending it, dropping it, standing on it, hitting it with a hammer, by poring very hot liquid on it or by making it resonate to a specific tone. Whatever method you chose, the glass will always *break when the maximal deformation is exceeded*. It is almost impossible to see the deformation of glass with the naked eye. But with a little help you can see the compressive deformation in transparent materials like glass very well. Deformation becomes visible under monochromatic polarised light with an instrument called a polariscope. This process is referred to as

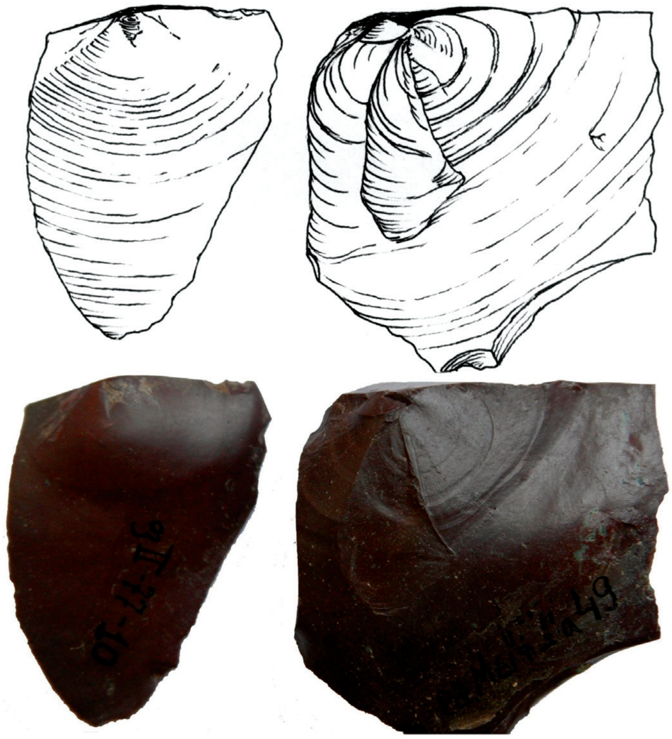


Figure 4: Comparing the ventral faces of a freehand flake (Acheulean from Chikiani) and a bipolar flake (Oldowan from Dmanisi). Freehand flakes show ripples inside the compressed cone area, bipolar flakes show ripples over the complete surface. This bipolar flake has a dead-end cone, just to the left of the contact-point where the fracture started. Such dead-end cones occur in bipolar experiments and are seen in the Clactonian industry. The very large bulbar scar indicates a very large force between hammer and anvil.

'photoelasticity'. Through the polariscope we see that a pointed compressive force produces a *ring-pattern similar to the eye-like rings on peacock feathers* (in French oeil de paon). These rings show us how the strain builds up inside the model. These rings appear because the compressed material tries to get out of the way of the force; just like the skin of your forehead wrinkles when it is compressed. With the difference that skin is very elastic and glass or stone is very inelastic; so what photoelasticity shows us is not the glass wrinkling but only the wrinkling strain pattern.

The rupture begins in the hammer-contact-point, where the compressive deformation is at its greatest. This is at the top of the peacock-eye-pattern. From there the rupture wants to go straight through the stone. But the pattern of the greatest strain goes back and forth in the peacock-eye-pattern. So the rupture must follow the *wrinkling strain pattern*, as a result the fracture shows *the footprint of the strain-wrinkles*, frozen in time at their peak during the rupture! The peacock-eye-pattern is visible in figure 4 on the right, this is not the pattern you may expect from transversal waves. An even more obvious pattern is shown a in figure 5. A gunners-target-like circular wave pattern is made in the drawing on the left side. But the photo in the centre of figure 5 shows us the reality is completely different. This real situation is drawn on the right, the ripples are clearly the result of compressive strain. The most explicit peacock-eye patterns can be formed by hard steel hammers, i.e. in the Eben-Emael porcelain-mill-lining industry (Slotta, 1980).

The ripples also help us to distinguish between freehand and bipolar flakes, because ripples only occur in compressed areas. The left drawing in figure 4 shows ripples *inside* the triangular cone area whilst the outer stretch fractures are smooth. This further increases the contrast of the bulb. In bipolar fractures, the ripples cover the complete surface (figure 4 on the right) because the complete surface was under compression during the fracture. This is exactly how a typical bipolar flake should look, but most archaeologists have false expectations: they believe bipolar flakes should show *bipolar ripple-marks*. De Heinzelin (1962) wrote that 'the shock-waves progressed from two opposed points of the same flake, but not always'. He probably imagined this because the ripple-marks in steep retouches used to blunt the back of Upper Palaeolithic blade-knives often come from both opposed sides. In our

Figure 5: The drawing on the left shows a circular ring-pattern, transversal waves would result in such a circular pattern. But the photo (part of a hand-axe of the Keilmesser tradition) and the realistic drawing on the right show a completely different ripple distribution; this pattern makes clear that the ripples are a strain phenomenon.

bipolar experiments we hardly ever see bipolar ripple-marks. The first reason is that peacock-eye patterns only occur if there is a small contact point. So you need both a small hammer-contact and an equally small anvil-contact-point to get double ('bipolar') ripple-marks. The second reason why bipolar ripple-marks are rare in bipolar toolkit groups is that bipolar flakes are not made in *straight* bipolar technique. Instead bipolar flakes are made in *oblique* bipolar technique (figure 6 drawing on the right). In this technique the fracture begins in one contact-point but never reaches the second contact-point. Because there is no second contact-point involved in the fracture, there certainly cannot be a second ripple-pattern.

The fact that there never are bipolar ripple-marks on bipolar flakes is probably the reason why Vértes wrote that bipolar reduction was not used because: 'no traces indicating such a technique can be seen either on the flakes or on the flake negatives' (Kretzoi and Dobosi, 1990). It is no surprise that Vértes did wonder if bipolar techniques were used because first of all it is simply impossible to work small rounded pebbles of 2 to 2,5 cm from the free hand. The second clue Vértes found was of course the presence of anvils in Vértesszöllös. And the third thing he noticed were the impact points 'on the base of some pebble chopping-tools and broken pebbles'. The absence of bipolar ripple-marks in Vértesszöllös and other bipolar industries is in complete accordance with our bipolar reduction experiments.

3.3 Bulbar scar and fissures

The rupture-front wants to progress in a straight and simple way through the strained-deformed material. But to make it a bit less simple: physics teaches us that all progression can be split into components or vectors. So we must split the progression of the rupture front into a component in the *most compressed direction* and a perpendicular component. Because the two components are confronted with different material properties they travel at different speeds. So simple physics causes the linear rupture to *become a spiralling rupture*. This creates a huge problem; the rupture is not simply allowed to follow a spiralling path because it is bound to the location of the greatest deformation.

This conflict between the obligatory fracture-surface (French: plan de rupture) and the tendency to spiral away during the rupture, shows up as scars. These scars are derailments; places where the rupture spirals out of its path. When these derailments stray too far from the surface of the greatest strain, they come to a sudden stop and the rupture restarts in the correct surface. As you can guess, these conflicts are at their worst at the places with the greatest deformation! In freehand flakes this is first of all just below the hammer-impact-point, on the protruding part of the bulb. As logic demands, this is called the bulbar scar (French: esquillement). As the rupture progresses further from the impact point, the compressive force disperses. So freehand flakes show no scars in the middle of the fracture face where the strain is lessening. But as soon as the rupture nears the cores edges (or cortex) the situation changes. Here at the rim, there is less surrounding material that resists the deformation, so even though the force is reduced, the actual size of the deformation increases! So here at the rim again we see spiralling derailments: these scars are called fissures (French: lancettes).

In bipolar fractures the scar and fissures can look very different because the forces are distributed in a different way. First of all: the blockage by an anvil leads to a much faster and more complete deceleration of the hammer than inertia. The forces in bipolar reduction can therefore be far greater than in freehand flaking. Greater forces can lead to larger bulbar scars as we can see i.e. in figure 4 on the right. The second change is that the greatest deformation occurs between hammer and anvil, so the bulbar scar can be formed anywhere between hammer and anvil. It can even be in the centre of the flake. This is very different from freehand reduction, where the scar is always near the contact-point. As the greatest deformation runs from hammer to anvil, the scar can run in this direction as we see in figure 4 and even more clearly in figure 9. The fissures in freehand flakes always radiate from the hammer-contact towards the outside of the core, therefore the Dutch name for fissures is radial rays (radiale stralen). But in bipolar fractures the fissures are directed from hammer to anvil because this is how the rupture front progresses. So instead of the nearly straight radial pattern in freehand fractures, the non-CF fissures tend to *curve from hammer-contact towards anvil-contact*.

3.4 Direction and platform

What happens when we strike a core from the free hand and hit it dead-centre? At first a fracture starts, we see the beginning of a neutral cone. But as this rupture progresses towards the centre of the core, the cross-section of the cone gets bigger and bigger. So the compressed area inside the cone increases exponentially (proportional to the square of the distance). This means the force per square millimetre quickly decreases, producing less and less deformation. So each conical fracture directed to the centre of the core quickly comes to a dead end. There can be no doubt that freehand flint-knapping only works if we can stop the increase of the compressed area. The way to do this is by directing the strike so that you *keep most of the cone outside the core*. The simplest way to do this is by keeping the core tilted and striking the lower edge. This is shown in the left drawing in figure 6. The red arrow in figure 6 is the strike that produces the light grey vertical cone. This cone peels away the black flake, the flake is only a small segment of the cone. Because only a small segment becomes compressed, the force per square millimetre stays high enough to propagate the rupture.

But this obligation to direct the cone away, creates the next imminent problem that we see in figure 6. You have to understand that the idiomorphic cone has an opening angle around 100 to 110 degrees (depending on the material). This means the actual fracture (which is determined by the direction of the neutral cone) runs at an *angle of 50 to 55 degrees to the direction of the strike*. So if we want to flake the cobble in figure 6 we must (as you see in the drawing) strike the surface at an angle of 35 degrees. This hardly produces an effective force because two thirds of the strikes force is already lost. This strike will bounce! To prevent a strike from bouncing freehand cores need a *striking platform at a correct angle*. The necessary platform for a successful freehand strike is shown in the grey flake drawing just to the right. So even though our cobble has a large flat surface, this can never work as a platform, because this cobble has been rounded off to much. This rounded cobble cannot be used in freehand reduction, unless you first break it 'open' with the use of an anvil!

Bipolar reduction works completely different. Freehand reduction is about directing the cone so you can *peel away layer after layer* of thin flakes, it both requires and produces acute edges. Bipolar flaking on the other hand can simply *cut away a large part* of the core in one blow, independent of the quality or shape of the raw material. The fracture simply starts in one contact-point and runs towards the other contact-point.

Straight bipolar reduction is like cracking a nut; the hammer hits the (top) centre of the core whilst the core rests with its (bottom) centre on the anvil. Therefore straight bipolar fractures include both the hammer-contact and the anvil-contact. If you want to break perfectly round pebbles, this nut-cracking technique is your only option. So it is obvious that the rounded pebbles from 2 to 2.5 centimetres in diameter that were used as raw material in Vértesszöllös could only have been broken in bipolar reduction. Freehand flaking was impossible for two reasons: there was no striking platform and the pebbles had too little counteracting inertia as a result of their small size.

The *oblique bipolar technique* is archaeologically far more interesting than the straight bipolar technique. This basic technique is shown in figure 6 on the right. I have called this technique 'oblique' because the strike is not directed straight towards the anvil-contact (van der Drift, 1991, 2001, 2009). Just like in freehand flaking the strike is most often simply directed downward,

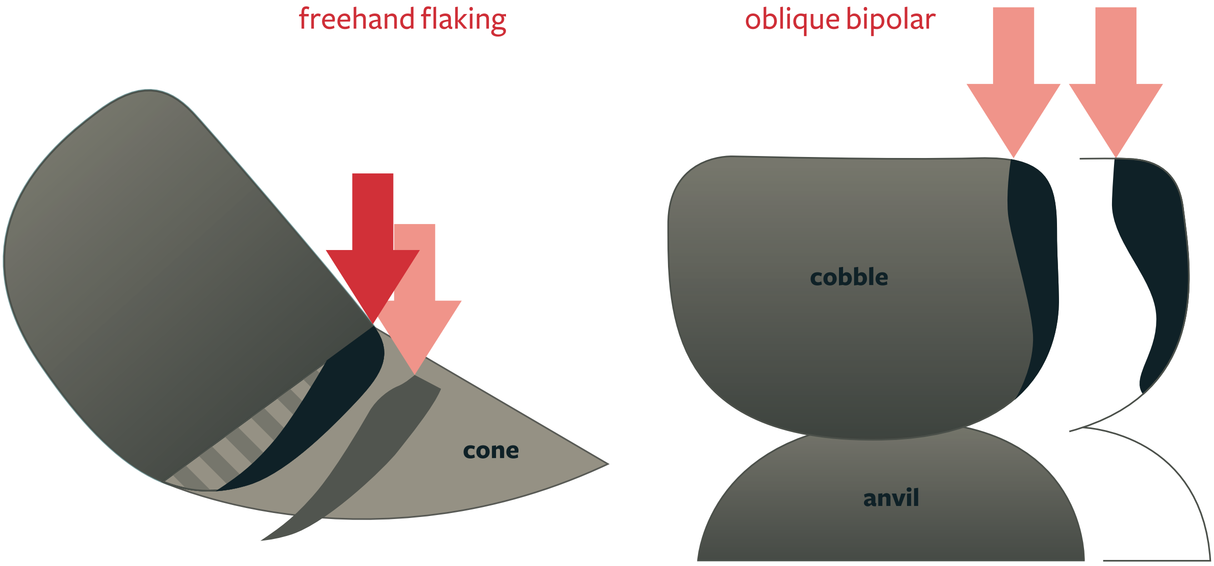


Figure 6: Flaking a cobble from the free hand (left drawing) is often impossible. In freehand flaking the shape of the flake (black) is determined by the direction of the neutral cone (light grey). To give this cone its correct direction, the strike (red arrow) must point out of the core. As a result the strike might very well bounce off; to prevent this a correct striking plane is essential (as in the grey flake). The right drawing shows that there is no cone in oblique (the strike does not point straight towards the anvil) bipolar flaking, the compression build-up is directed towards the anvil contact point. This makes an effective strike (pink arrow) possible without the need for a 'correct' striking plane. The use of an anvil also leads to a greater effective force resulting from the strike. In oblique technique only one contact point is involved in the fracture.

the correct flaking angles can be controlled by careful positioning of the core. But instead of *tilting* the core as in the freehand reduction, *sliding it forward or backward* changes the flaking angle. To understand this better, we can split the force from the strike into two vectors. The first vector points towards the anvil contact, this force initiates and propagates the rupture. And the second (perpendicular) vector pushes the rupture towards the outside (cortex) of the cobble. There is yet another reason besides this second vector that pushes the rupture towards the outside of the core; the deformation is easier near this outside. So just like in freehand fractures the flakes tend to follow the ribs because the deformation facilitates this (see van der Drift, 2001, 2009). *As a result the oblique bipolar rupture in figure 6 never reaches the anvil-contact*. This produces oblique bipolar flakes, that closely resemble freehand flakes. The flakes from Dmanisi shown in figure 4 on the right and in figure 7 and 9 and the front page are good examples of oblique bipolar flakes.

The flake from Dmanisi in figure 7 shows more resemblance to a flake from a prepared core. But when we look at the drawing on the left, we see what the flake would look like, if it had been made from the free hand. At about 125 degrees to the fracture surface we can reconstruct the direction of the supposed freehand strike (red arrow). But since there is no platform this strike would bounce. A platform at the correct angle is therefore drawn in blue. Of course the blue would-be strike on the blue should-be platform would have produced the blue protruding bulb. Next the freehand fracture would be following a parabolic curve towards the distal rim (Bertouille, 1989, van der Drift, 2009), this curve is shown in lighter blue. But the reality of the Dmanisi flake in figure 7 is very different. There is no platform, the bulb shows absolutely no contrast and the flake is not parabolic, making this a definite non-CF artefact. To make the picture of a bipolar tool complete this Dmanisi flake has a denticulate edge instead of regular retouches. Both the flakes in figure 4 and 7 seem to have a correct direction and platform for freehand flaking. It is nevertheless obvious that both are oblique bipolar flakes; both have diffuse bulbs, the bulb in figure 4 can

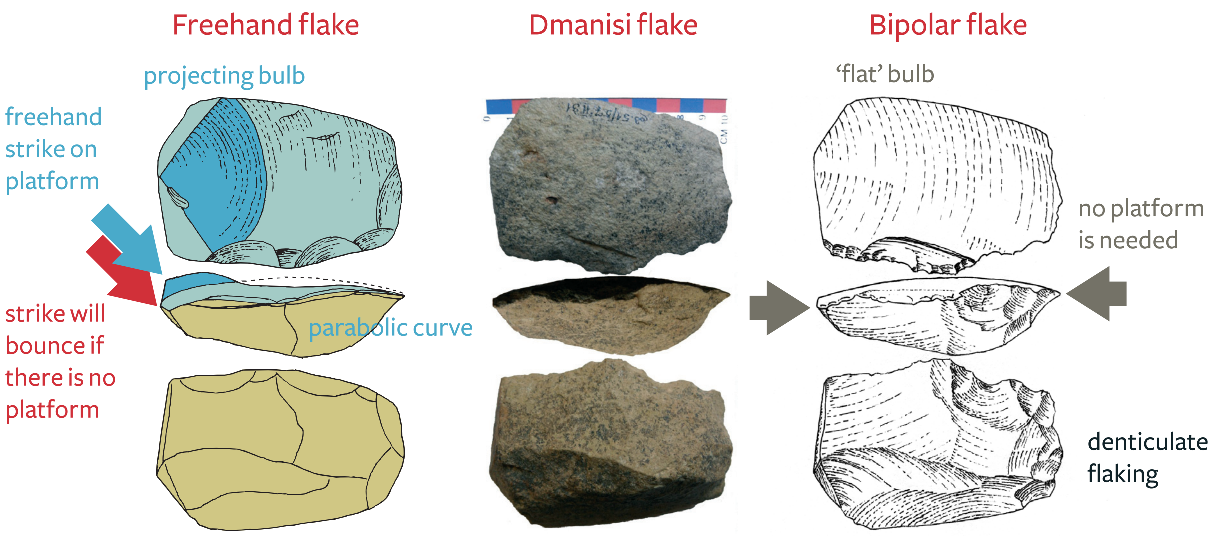


Figure 7: This flake in volcanic tuff from Dmanisi resembles a freehand flake from a prepared core. The CF signs which are essential in freehand flaking, are shown in the drawing on the left. A freehand flake needs a striking platform and a projecting bulb leading to a parabolic fracture. But the photo shows that the flake from Dmanisi misses these CF signs. The drawing on the right shows the real fracture was non-conchoidal and therefore made in bipolar technique.

be called heavy and in figure 9 flat. And both have large hammer-to-anvil directed scars.

Paragraph 2 and 3 have now given us a completely different perspective. We have seen that the Dmanisi has always been interpreted as a hominid site following algorithm A; there are manuports and hominid fossils in an ideal site. But algorithm A led everybody to the incorrect assumption that the flakes were struck from the free hand. Oblique bipolar flakes have been mistaken for freehand flakes in many sites because they: *1 often show a bulb *2 often show a scar *3 often have a striking plane and *4 often show a single ripple pattern. A good understanding of the CF signs and close inspection is necessary to see that: *1 the bulbs are often diffuse *2 scars can be large *3 striking planes can be at any angle and *4 ripple patterns can be present outside the cone. The correct interpretation of the site then follows from algorithm B.

4 Bipolar tools

Recognizing the diagnostic signs of CF (as discussed in paragraph 3) is the correct way to differentiate between freehand (CF) and bipolar (non-CF) reduction. But even without studying the diagnostic signs, the general character of the toolkit often gives us an idea whether freehand or bipolar reduction was used. Some tool-types and the way in which these were made can be linked to either freehand or bipolar reduction.

4.1 Different mental templates

Hand-axes are commonly present in Palaeolithic freehand industries, but bipolar industries never made deliberate and repetitive hand-axes (van der Drift, 2007). The reason is that hand-axes are directly linked to the dynamics (in French gestes) of freehand flaking. When you strike a flake in a freehand experiment, you want to see how the removal has affected the core. But in flattened cores the removal can only be seen from the bottom-side. So every time you have struck a flake, you need to turn the core upside-down to see the result and determine the place and direction of your next strike. Turning the core over and over and over again, puts the idea in your mind that the core has two sides (*dorsal and ventral*). Flaking both the dorsal and the ventral side is done from the edge and results in an alternating zigzag style. This idea of flaking two-sides objects is called the '*bifacial mental template*' and it inevitably leads to making hand-axes. The form of hand-axes is further perfected by invasive flaking all-over both faces, this *reduces the thickness*. This was of course done to make more efficient *acute cutting edges*. This shaping technique (façonnage) was the basic mental template for the Acheulean (Turq, 2001). New reduction strategies were added to the freehand techno complex during the Middle Palaeolithic (figure 8), but at all times the mental template of an object with a dorsal and ventral side remained the origin of: 'the universality of flat bifacial retouch' (Otte, 2001) in freehand assemblages.

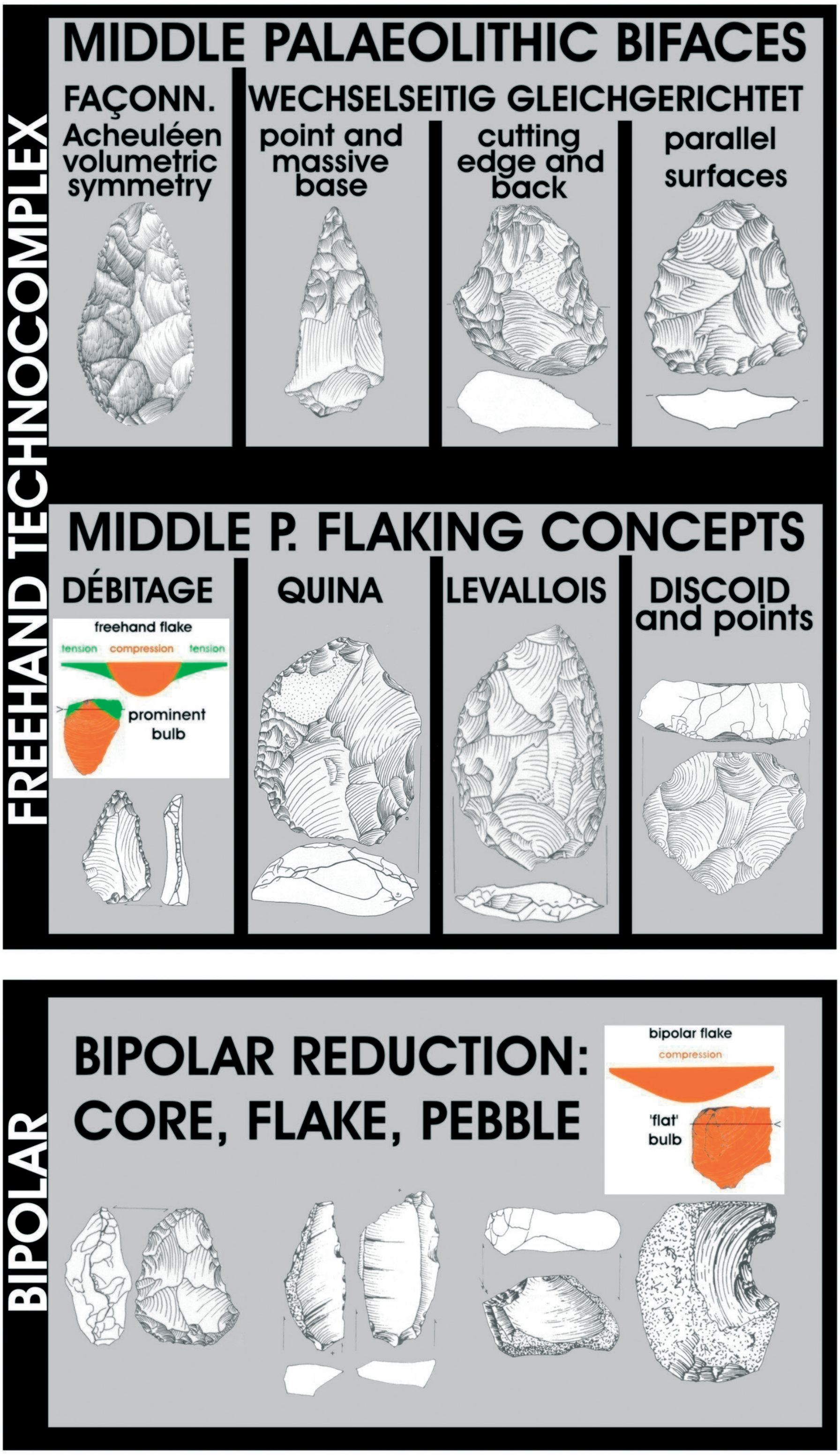


Figure 8: The freehand techno complex started out with debitage and façonnage. And during the Middle Palaeolithic time span new reduction strategies were developed. The bipolar toolkit concept did not develop new reduction strategies, the industries remained simple flake and core based or pebble based. The trimming of the techno-functional units did show some development in time, well developed microlithic toolkits are seen in industries of the Middle Palaeolithic time span.

The bipolar toolkit concept asked for a very different mindset, because the dynamics (gestes) were very different from freehand flaking. The first step was the selection of cobbles, these were then put on either the ground or an anvil in the most opportune positions to flake them. But completely in contrast to the freehand reduction there was no need to turn the cores over and over again. As a result 'the universality of flat bifacial retouch' (Otte, 2001) never developed in bipolar traditions; there are no flat hand-axes in the Tayacian, the Clactonian or in pebbletool industries. Because cobbles were often abundant, it was easy to produce great numbers of primary forms. And the ones that seemed best fit for the job were selected. These selected shapes were used as a carrier (French: forme de support) for the tool. The techno-functional units (UTF in French: Unités Techno-Functionelles, Boëda, 2001) of the tool were then made by secondary trimming. The mental template of bipolar tools can therefore only be recognized from this secondary trimming.

4.2 Shaping tools

Straight bipolar reduction (nut-cracking technique) is the preferred method for opening round cobbles and for making pebble segments. Pebble segments are angular shapes, they were described by Vértes (1965, Kretzoi and Dobosi, 1990): he recognised a split pebble group with hemiliths, ortholiths, plagioliths, quarter pebbles and smaller than quarter pebbles. And also pebble slices, pebble segments, polyhedrons and pebble points.

The second bipolar technique: *oblique bipolar reduction* shown in figure 6, was the most basic technique for making flakes and also for secondary trimming. Oblique bipolar flaking therefore determines the dynamics of the shaping of bipolar tools, many variations are possible. For starters different anvil types can be chosen; the ground can be used as soft anvil, a hard flat anvil can be used, pitted anvils (this 'nut-cracking' type is shown by Prous 2009 fig 33 and was already present in Olduvai) or the exact opposite: anvils with a sharp ridge or point. These anvil variations are all deliberate and functional choices. The second variable is the position of the core. The core can be shifted into a more central position fully supported by the anvil, or held more eccentric supported by the hand. The third variable is the hammer-impact-point (and less important the direction of the strike). By changing the position and hammer-contact-point thicker or thinner flakes can be made at a more or less acute angle.

One version of the oblique bipolar technique needs our special attention: the 'upside-down' oblique bipolar technique. What this means is that the edge of a core (or the edge of a flake or pebble segment) was carefully positioned onto the anvil. For this careful positioning an anvil with a sharp ridge or point often came in handy. When everything was in position the object was simply hit dead-centre; the consequence of hitting the core dead-centre is that it is very unlikely that the fracture is initiated in the hammer-contact-point. The rupture therefore started in the anvil-contact-point. That makes the *upside-down oblique bipolar technique ideal for secondary trimming*. It is so practical that I prefer this in my experiments over the normal oblique bipolar technique (where the hammer initiates the fracture, see figure 6). Firstly because it allows for *careful positioning* and secondly because the *trimming is visible* immediately as you make it. The fact that you can see the results of your actions during the process of upside-down oblique-bipolar trimming stands in total contrast with freehand flaking where you always need to turn the object over. This upside-down oblique bipolar technique certainly did not stimulate the development of the bifacial mental template.

In my experiments I prefer to make large primary flakes in the normal oblique bipolar technique (as in figure 6) using the ground as soft anvil. But if you make flakes in the upside-down oblique bipolar technique (on a hard anvil), there often is a wider oval contact-area between the core and the anvil. When the fracture starts in a wider contact area this produces a 'lip', just like the lip that is often seen in soft hammer flakes. In figure 9 a basalt experimental upside-down bipolar flake with such a lip is shown. The same figure shows a large basalt flake from Dmanisi with such a lip (also in plate 8 in de Lumley et al, 2005) which bears resemblance to a freehand blade with a feather ending. Closer inspection leaves no doubt that this is a bipolar flake, because the ventral face shows a flat bulb with a very long scar stretching over half the ventral surface.

If the contact point initiating the fracture is further from the edge, very deep flaking negatives can be produced. As a result bipolar trimming can produce characteristics which are uncommon or sometimes even impossible in freehand technique. Such as denticulate retouch (Tayac-points are by definition denticulates) and deep notches (encoches or Buchten, two adjoining notches can form a beaked or rostrocarinate tool). If the hammer and anvil contact points are almost directly above each other this can produce steep or sometimes even obtuse retouch (i.e. figure 12). Bipolar trimming was also used to make resharpening spalls. Pointed tools (beaks, rostrocarinates) were often sharpened or resharpened by burin-like flaking. These burins are

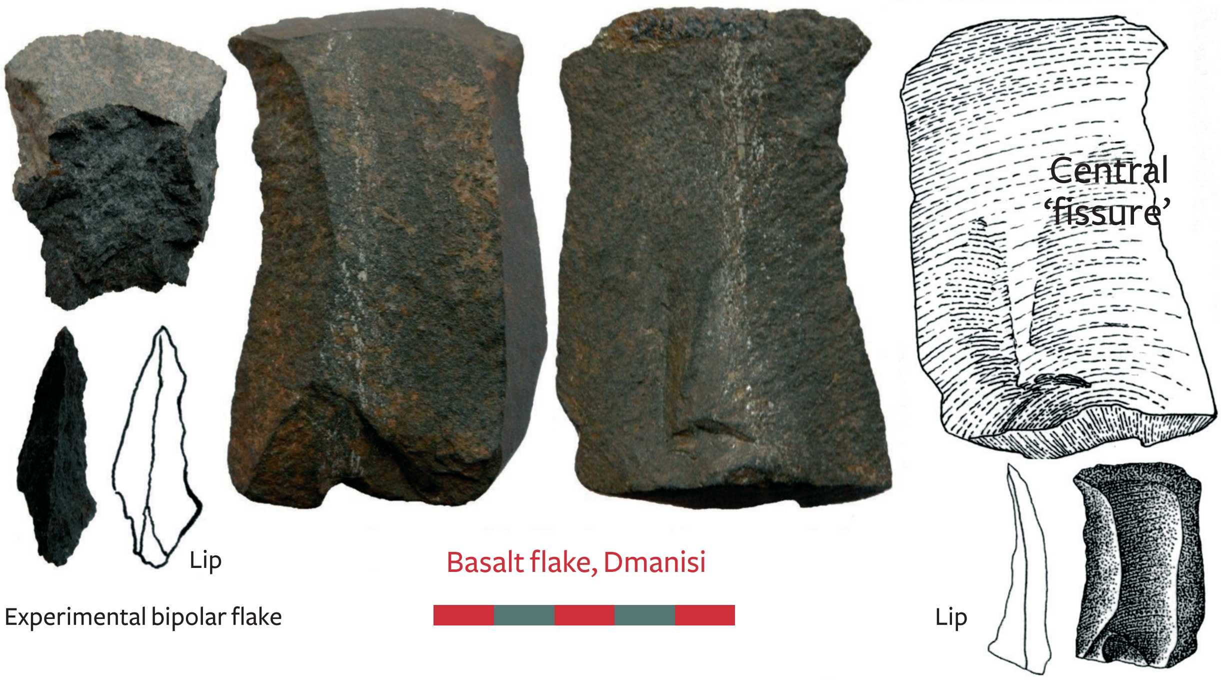


Figure 9: The presence of a platform, bulb, scar and a feather ending is definitely not enough to conclude that a flake is conchoidal. This large basalt flake from Dmanisi has a flat bulb (paragraph 3.1) and a stretched central scar (paragraph 3.3), making it a definite non-CF bipolar flake. The lip is seen in bipolar experiments when the fracture is initiated in a larger contact area.

seen in the Oldowan, Developed Oldowan, Clactonian and Tayacian. Of course this Old Palaeolithic tool-type is not the Upper Palaeolithic burin intended for fine engravings; bipolar burins were merely a 'short, thick-set working edge' (Leakey, 1979). But the Upper Palaeolithic burin was sometimes made in the same upside-down oblique bipolar technique because in this way straight cutting edges can be made (Bertouille, 1989).

Bipolar trimming produces a wide range from obtuse to very acute angles, the most acute bipolar trimming is seen in the Upper Palaeolithic. Hamburg end-scrapers on blades show retouches up to 30 degrees, these scrapers were trimmed with oblique bipolar technique. This trimming is commonly called 'contre-coupe', hammer marks are sometimes found on the dorsal side. For the purity of my arguments I must add that contre-coupe is not bipolar in the strictest sense because the hammer-contact and anvil-contact are *so far apart that neutral cones do develop*. We are trained to believe that acute edges are always better and more efficient. But there is a very different way in which we can appreciate the sometimes very steep trimming. This is best understood when we start out with only pebbles for raw material. The straight bipolar technique produces many hemiliths (half pebbles) and we want to trim these basic shapes into scrapers. It is very obvious that hemiliths have an edge that is much steeper than in most flakes. The steepness makes it simply impossible to trim the cortex from these hemiliths with the use of freehand technique. Bipolar trimming on the other hand is easy in spite of the steeper angles. *So instead of looking at steepness as a problem, we have to learn to see this as an extra option*! Due to the quality of the raw materials, steep retouch often was the only way to trim a thick basic shape into the desired tool-type.

A very important difference between freehand shaping and bipolar shaping is that bipolar tools can be made on very poor quality raw material, such as small pebbles or volcanic rock types. The shaping of freehand tools is strongly influenced by the fact that good quality raw material is needed, because this raw material is often *scarce*. The scarcity makes the freehand technology focus on reusing cores and resharpening tools to their very limits. This leads to intensely worked *'curated'* technology (Binford, 1977) with deliberate form shaping. Without scarcity the Levallois technique, reusable hand-axes, Quina resharpening and volumetric blades would probably never have developed. The raw material scarcity was no issue in making bipolar tools, because these could be made on very poor quality raw material which often was plentiful. As a result the bipolar reduction focuses on *'expedient'* technology (Binford, 1977). Camps were often very close to raw material sources (i.e. riverbeds), making it easier to create a new flake than to clean and resharpen a used flake.

Mania and Weber (1986) called straight bipolar reduction shattering (zertrümmern). Shattering is the absolute opposite of directional control, but despite of this bipolar traditions still show clear standardisation. Prous et al (2009) even call bipolar industries '*statistically precise*'. What Prous means is that the shaping of a hand-axe is 'individually' precise: each individual hand-axe has been made by deliberate volumetrically symmetrical (Turq, 2001) bifacial flaking. Whilst the standardisation in bipolar industries is based on *selection*. The selection starts with raw material procurement; the best rocks or cobbles or pebbles were selected and reduced to primary forms (flakes, cores and pebble segments). From these the best were selected as carrier for the UTF or techno-functional units and shaped by secondary trimming. When you reduce enough rocks or pebbles, you may 'statistically' expect that the primary form you desire will surely be amongst the 'zertrümmerte' debris. Prous et al (2009) call this an *opportunistic selection of adequate products through a statistical expectancy* ('choix opportuniste des produits adéquats, prévus statistiquement'). So through 'statistical' selection, the bipolar toolkit could offer the 'precise' basic shapes that were trimmed into tools. This secondary trimming was subject to a well defined mental template, and therefore led to recognisable standard types. This made bipolar reduction an overwhelming success during the Palaeolithic.

4.3 Bipolar tool-types

Oblique bipolar reduction first of all produces cores and flakes, these cores and flakes are often mistaken for freehand forms. We have already seen examples of bipolar flakes from Dmanisi, both Clactonian type (fig 4) and non-Clactonian type (fig 7 and 9). Figure 10 shows a clear example of a core that was made in bipolar technique. You can get an impression of the massive size the original cobble might have had, from the convex edge visible in top view. This massive core was at first broken in straight bipolar technique, producing the top striking platform. Then the largest flaking negative in the bottom view was made, by resting the split cobble on a hard surface (black circle in the drawing) and striking it (black triangle). It is probable that this preparation of the cobble-segment was done where the raw material originated (river bed) and that the cobble-segment was then transported to the living area. Because the next strikes are different, these were made using a softer floor as anvil (grey circle) from the top down (grey triangles). It is very evident that these flaking negatives are not from freehand strikes because the hammer struck very far from the edge creating deep concave scars. Placing the hammer far from the edge means that much extra force is needed to initiate the rupture, therefore such concave fractures do not result from freehand technique.

Bipolar tool-types with secondary trimming are also misunderstood and not properly defined. I would like to start with the bill-hook. This is considered to be the classic Clactonian tool-type, it combines a deep notch with a retouched-blunted grip (une troncature, Bordes, 1968). this is shown in figure 11. To understand this tool-type we must first understand the deep notch (in French encoche or in German Buchten, Mania and Weber, 1986). *Deep notches are a specialized oblique bipolar trimming technique*. We should not confuse these deep notches with the 'milled notches' made in the thin edge of a flake, which are common in freehand traditions (i.e. Moustérien à denticulés). It is impossible to make deep notches in cobbles or massive flakes from the free hand, but in bipolar technique making a deep notch is actually rather easy. Notching is essentially the same as all other oblique bipolar trimming but the contact point where the fracture is initiated needs to be further away from the edge. You can strike a deep notch with the core supported by the earth (the notch is formed from the hammer downward), so very similar to making the deep flaking negatives we have seen in figure 10. But it is also possible to make the notch in upside-down technique. By carefully positioning the primary form on a pointed anvil (just a bit further from the edge) and striking it more centrally, the deep negative forms from the anvil upward. Clactonian bill-hooks were used as concave scrapers and the edges of the notch were also used as cutters; this can be concluded from the resharpening-flake-removals in burin or rather 'Pradnik-spall' style (van der Drift, 2010c) that we see for instance in figure 11.

There is much confusion about *so-called 'bifacial' artefacts* in bipolar assemblages. Because the bipolar toolkit concept has no bifacial mental template there is no real flat bifacial retouch. But of course there are many tools with secondary trimming on two or more sides. Due to the lack of understanding of the dynamics of bipolar reduction, these trimmed tools are carelessly called 'bifacial', these forms are mistakenly believed to have been flaked from the free hand (Mania ,1990 p. 121, pp.178-179) and they are *mistakenly linked to Mode-II* or even to hand-axe production. They are merely primary forms *with trimming on more than one face.*

Of these tool-types with trimming on more than one face, I want to start with the Tayac-points (figure 12). Tayac-points are defined as converging denticulates

Core from cobble-segment

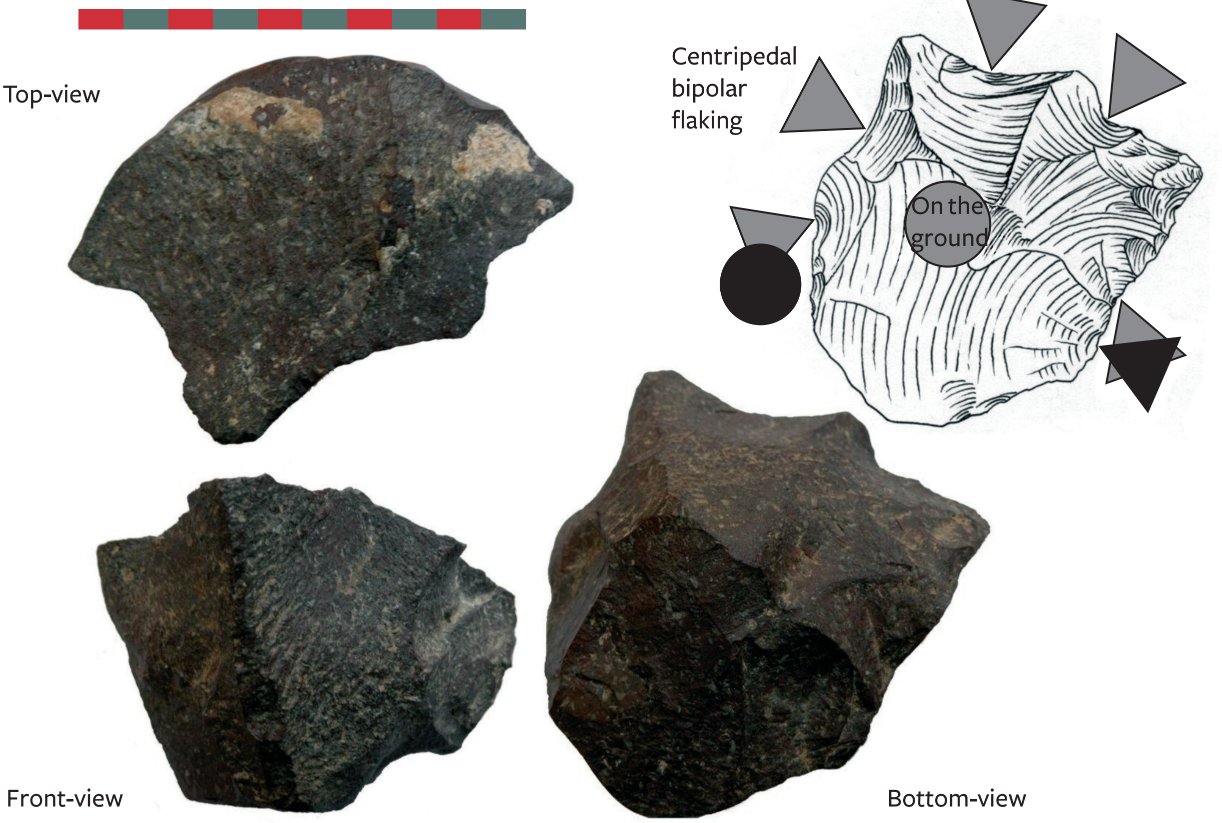


Figure 10: Bipolar core from Dmanisi made from a basalt cobble segment. The cobble segment (made in straight bipolar technique) has been flaked on the ground (in oblique bipolar technique), leaving deep concave scars that curve inward towards the ground-contact-area.

(Bordes, 1954); in other words tools that have irregular trimming and a pointed shape. De Heinzelin (1962) calls the trimming type: 'macro-encoches'. It is no surprise that we find these denticulate edges, because denticulate flaking often originates spontaneously in bipolar experiments (van der Drift, 2010b). Again I want to stress that the primary carrier shape (French: forme de support) of a Tayac-point is not made with bifacial façonnage as if it was a small hand-axe. Instead Tayac-points were made on a variety of bipolar primary forms: cores, flakes and pebble segments of the desired shape could all be used. The selected basic shapes often had a triangular cross-section (clearly visible in Mania, 1990 figure 100), standing in contrast with the lenticular cross-section (Turq, 2001) in freehand bifacial points. Since many primary forms were used of course the tool itself shows variation. Thick Tayac-points were probably scraping tools and short cutters, so these were close in function to bill-hooks. Figure 12 on the right shows such a thick converging denticulate, when you turn the picture upside-down the resemblance to a bill-hook becomes obvious. Thin Tayac-points on the other hand could have had a function closer to the function of freehand bifacial points (cutting or butchering tools), two Tayac-points made on thin flakes are shown in figure 12 on the left. Thin Tayac-points are also shown by Mania (1990), he called them special flint tools, points with one or two-sided flaking (Spezialgeräte aus Feuerstein. Ein- und zweiflächig retuschierte Spitzen). De Lumley et al (1979) show typical Tayac-points from the Tautavel cave, the toolkits from Tautavel and Bilzingsleben are very similar to eachother.

I want to continue the tool-types with trimming on more than one face by really going back to the most basic tool-type: the chopper. The French term galet aménagé can be translated as a pebble that has been modified. The general consensus is that this modification was done from the free hand by alternating reduction; as if choppers were made like hand-axes in a very clumsy unsuccessful way. We can read this in Mania and Weber (1986 p.136): alternating flaking, a continuous change of striking face and reduction face, is considered to be characteristic for the making

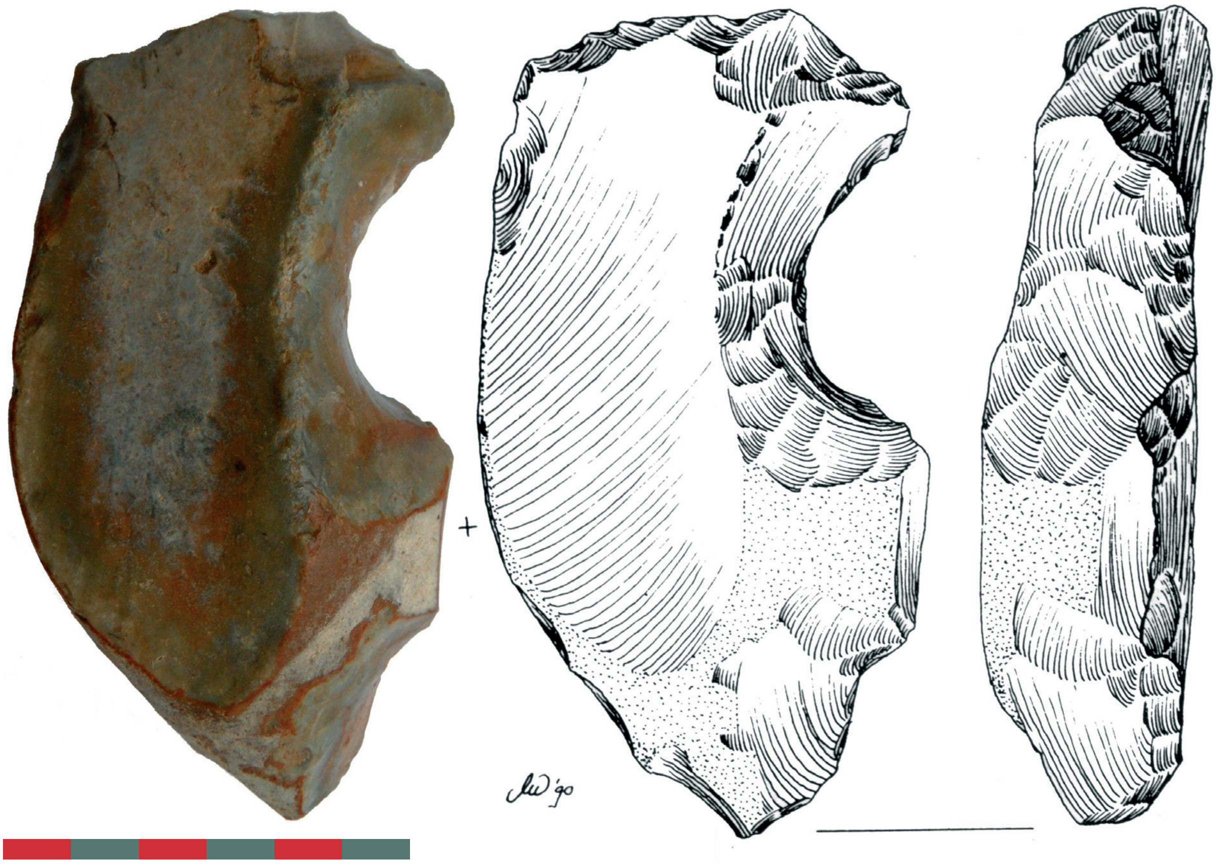


Figure 11: Bill-hook from the Clactonian from Berg & Terblijt. The primary shape (forme de support) is a parallel slice, slicing is a bipolar reduction technique. The deep notch cannot be copied from the free hand. Note the steeply retouched/blunted finger grip at the top and the burin like removals at the edges of the notch.

of chopping tools with a zigzag cutting edge (Die alternierende Bearbeitung, ein kontinuierlicher Wechsel von Schlag- und Abbaufläche, wird als ein charakteristisches technologisches Merkmal der Herstellung von Geröllgeräten mit gezakter Schneide gewertet). So let us see what happened when Mania and Weber put this idea to the test, by counting the tools with bifacial trimming in Vértesszöllös and Bilzingsleben. Even without paying attention to the zigzag-alternating character, only 40 out of 652 examined pieces from Bilzingsleben showed bifacial trimming. So Mania and Weber concluded this was too little to characterize Bilzingsleben as a pebbletool industry. The proper conclusion should of course have been that Bilzingsleben is no hand-axe industry because alternating bifacial reduction is typical for hand-axe industries. But it gets even stranger for Mania and Weber of course found a similar outcome in Vértesszöllös: only 4 out of 34 examined pieces showed bifacial trimming. Should they now conclude this was too little to characterize Vértesszöllös as a pebbletool industry? This would have put them in an awkward spot because Vértesszöllös is the most renowned pebbletool industry ever! Mania and Weber had the good fortune to find a way out of this awkward situation: the sample was too small to produce statistical proof, so they could simply ignore the conclusion... This clearly demonstrates that the general consensus on choppers must be revised. We must first understand that two distinctly different classes of choppers existed. The first group is formed by the choppers in freehand hand-axe industries, these are thin forms with an acute edge made by bifacial shaping. Such choppers can be compared to very short and simple bifacial backed knives (biface à dos, Keilmesser). The second class of choppers belongs in the bipolar industries, these bipolar choppers are *pebbles and cobbles that have been selected as primary carrier form, modified by secondary bipolar trimming*. This definition as 'pebbles and cobbles as primary form, modified by secondary bipolar trimming', explains that bipolar choppingtools are not reduced on two faces with the purpose of making a flat shape. The name choppingtool is therefore in bipolar assemblages not really meaningful.

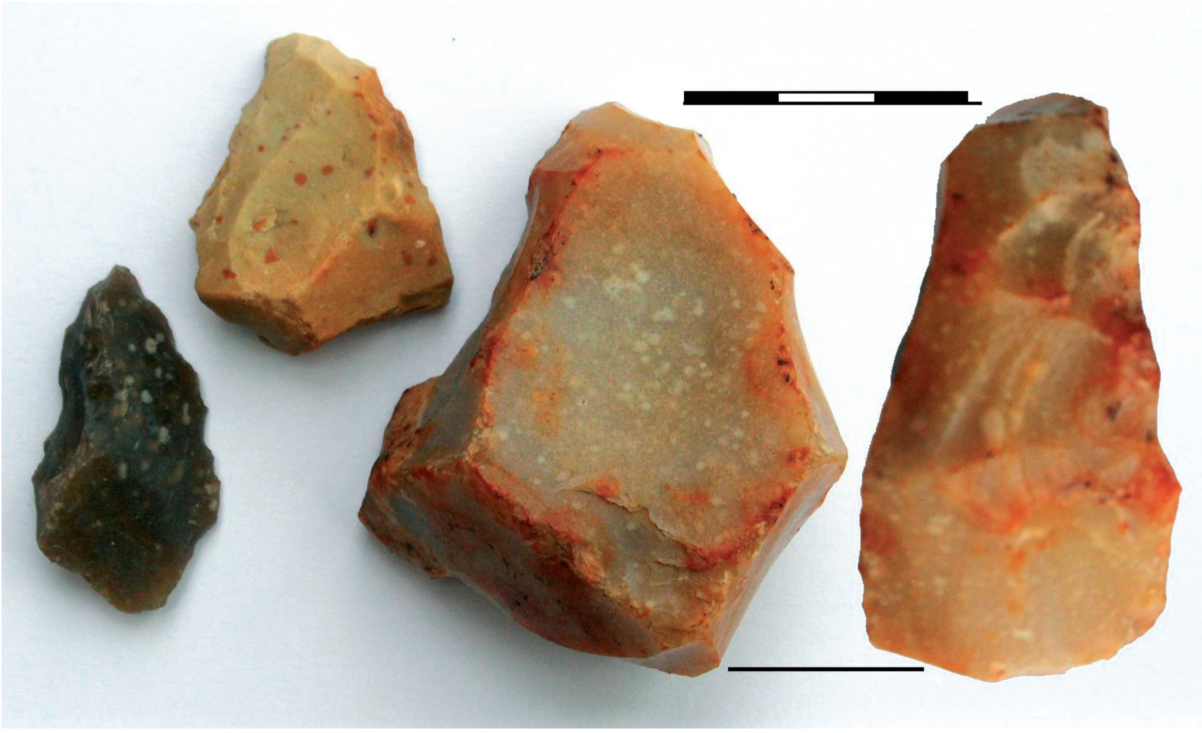


Figure 12: Tayac-points. Left two thin points on flakes from Mechelen. The Tayac-point on the right from Gulpen was made on a thick flake. The concave left side looks similar to the notch in a bill-hook and probably had a concave scraping function. The right side shows steep secondary flaking at an angle of 90-100 degrees. Making steep flaking angles is easy in bipolar reduction technique, if the hammer-strike is placed directly above the anvil contact (straight bipolar percussion) the flaking angles will of course average 90 degrees.

One chopper-type needs our special attention: the bipolar pointed chopper. Pointed choppers are pebbles and cobbles but in many cases also other primary forms such as cobble segments, that have been modified by secondary bipolar *trimming into a pointed shape*. These pointed choppers are often triangular in cross-section. This cross-section of course sets them apart from 'the universality of flat bifacial retouch' (Otte, 2001) and it unites them with for instance the Tayac-points. The triangular cross-section is often the result of a triangular primary form, in combination with secondary bipolar trimming. This trimming facilitates making a triangular shape because (unlike in freehand flaking) it is often steep. And the use of the upside-down oblique technique reduces the occurrence of alternating retouches in pointed choppers. These general principles of the bipolar pointed choppers make it easy to understand that Abbevillian hand-axes (fig. 14) and picks are closely related to pointed choppers.

The term Abbevillian hand-axe (coup de poing Chelléen) should of course be used with reservations because it was never properly defined. The 19th century collectors of the Abbevillian hand-axes were obsessed with evolutionary progress, therefore they created *what they believed to be 'development' lines* from crude triangular Abbevillian forms to thin biacial Acheulean hand-axes. This created a cultural mix-up in the old collections, causing Bordes (1961) to write that Abbevillian bifaces could be made by hard hammer but not necessarily, although it is said *on an anvil* (au percuteur dur, mais pas nécessairement, quoiqu'on en ait dit, sur enclume). De Heinzelin (1962) believed that the Abbevillian hand-axe was developed from the principle of the choppingtool. This was based on the general misconception that choppingtools made by alternate flaking would evolve to Abbevillian hand-axes, these should therefore have zigzag cutting edges and invasive flaking nearly covering both faces. And this again should evolve to real hand-axes. The pointed-chopper-resembling Abbevillian hand-axe is of course a completely different tool as we can see in figure 14. Because the old collections were mixed-up Tuffreau and Antoine (1995) advised to abandon the term Abbevillian, but that would of course leave tools such as figure 14 without a type-name. Closely related to the Abbevillian hand-axes are bipolar picks (pic-trièdrique or biface-trièdrique) which have of course been mixed-up with

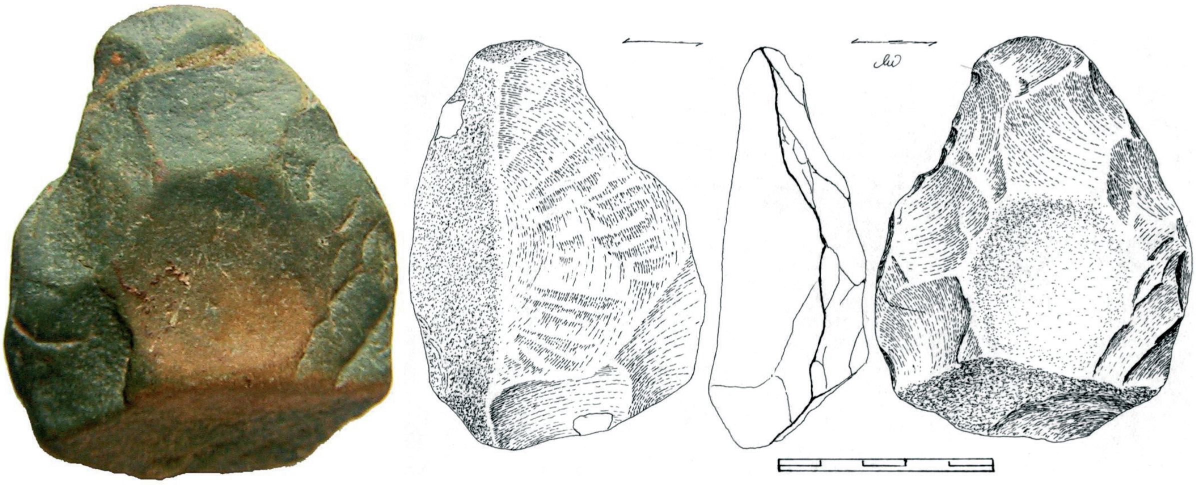


Figure 13: A resharpened large quartzite bipolar (non-CF) flake from the Oldowan finds from Gulpen (van der Drift, 2010a). Resharpening such a flake in steep bipolar reduction could turn it into a scraping tool. Here however the thin edge seems to have been resharpened from the free hand, resulting in a large cutting tool (LCT). Note the absence of alternating façonnage technique; this tool is not a hand-axe.

freehand pics (Bordes 1961).

5 Bipolar toolkits

5.1 Oldowan toolkit

Ethological studies have shown that both monkeys and apes crack nuts on anvils. And australopithecines that wanted to get at the marrow in fresh bones, must have broken these on the floor. Even for us today, it 'comes natural' to break objects on the floor or on an anvil. So the most logical conclusion is that the earliest stone artefacts must have been made in this 'natural' bipolar style. This conclusion is affirmed by the presence of irrefutable non-CF signs on Oldowan artefacts, as we have seen in the figures 4, 7, 9 and 10. It is furthermore affirmed in the presence of anvils. And furthermore by the fact that Mgeladze et al (2011) observed that as much as 54.6% of the broken cobbles in Dmanisi showed impact points indicating what they call 'bipolar percussion on anvils'. And more affirmation that bipolar technique was used comes from the tool types; simple flakes and cores and pebble-tools. The ratio of cores and flakes versus pebble-tools depends on the raw materials. And of course the raw materials also influenced the degree of secondary flaking because it is useless to try to resharpen coarse-grained flakes when you are producing expedient technology with plentiful raw material (van der Drift, 2010a). An Oldowan group made on high quality flint and therefore richer in secondary flaking and resharpening is shown by Lagerwey et al (2009).

The concept that Mary and Louis Leakey had of Oldowan tools was based on retrograde analogy; they believed the Oldowan was a pre-Acheulean, where hominids were learning how to master hand-axe technology. That made the Leakeys very keen on showing a 'gradual development' from Oldowan choppers towards Acheulean hand-axes. But of course there was no gradual transition from Oldowan to Acheulean (Leakey, 1979). Still Leakey held on to the theory that choppers gradually developed into proto-hand-axes and these 'unskilful attempts' were 'later perfected' into real hand-axes (Leakey, 1979 page 112). Neither Movius (1955) nor Leakey ever suspected that the Oldowan and Acheulean proto-hand-axes were completely different tooltypes based on completely different dynamics. The Oldowan choppers and proto-hand-axes were made on an anvil and could therefore never reflect a first step towards freehand reduction, there is no transitional 'proto-hand-axe time-span'. What really happened is that the Oldowan developed into the Developed-Oldowan. And the Acheulean appeared relatively abrupt next to this Developed-Oldowan.

This still leaves us in need of an explanation, how did the shift from bipolar (Oldowan) to freehand (Acheulean) technique take place? Figure 13 helps us to understand this. We have seen in the examples from Dmanisi that bipolar industries often made large flakes. Figure 13 shows us a similar large bipolar Oldowan flake from Gulpen (van der Drift, 2010a). This flake was struck on the ground (as soft anvil) from a large fine-grained quartzite core. The 1.8 Ma Meuse riverbed at Gulpen mostly held smaller sized cobbles, so such large flakes were scarce. As a result of this scarcity, this large flake was valuable enough to be resharpened after it became blunt. The secondary flaking we see in figure 13 could theoretically be made in upside-down oblique bipolar technique, but it was easier to work the thin edge of the flake from the free hand. Therefore it is more likely that this series of secondary flakes was struck in freehand technique, producing a 'Large Cutting Tool' or LCT (after de la Torre & Mora, 2005). I want to stress that right here the term LCT is not simply a synonym for tools-resembling-hand-axes (as in McNabb et al, 2004 or Sharon, 2007). De la Torre & Mora (2005) noticed many of these LCT's in Olduvai at the onset of the Acheulean tradition (before 1.6 Ma). The other tool-types in these LCT sites demonstrate that bipolar reduction was still used; for instance Leakey's 'diminutive hand-axes' are bipolar pointed choppers (de la Torre & Mora classify them as 'chunks'). Because large cutting tools are highly functional in open landscapes, making LCT's soon became a specific application in Olduvai. The flat cross-section of these large flakes invited to turn them over, resharpening them from both sides. This strategy led to the bifacial mental template. This early freehand-bifacial mental template soon changed the complete reduction strategy into the 'Mode-II' Early-Acheulean concept with façonnage. In this Early Acheulean the LCT's had become real hand-axes and the other tool-types were replaced by freehand tool-types. Just half a million years later, around 1.1 Ma, the prepared core technique was developed, bringing the 'Mode III' Middle-Acheulean (Beaumont and Vogel, 2006).

5.2 Clactonian toolkit

Comparing toolkits made it very clear to Leakey (1976) that the Clactonian and Tayacian industries were the European counterparts of the African Developed-Oldowan. The Developed-Oldowan existed simultaneous with the Acheulean in Africa, so it should not surprise us that the Clactonian and Tayacian and pebbletool industries existed simultaneously with the Acheulean in Europe as well. In the Netherlands some bipolar sites can even be dated in the Eemian. For instance the Tayacian traditions from Huizen (Walet en Boelsma, 2000) and Texel (van Noort 2010) and the Clactonian 'Waldgroup' found by Geertsma & Geertsma in Schuilenburg and Broeksterwoude (van der Drift, 2007).

The general misunderstanding of the Clactonian started with the scientific consensus that Clacton-flakes are just simple freehand flakes. The Clactonian was found near Mesvin around 1890 and later in Clacton on Sea. It was thought that this industry predated the invention of hand-axes. Hand-axes were made in freehand technique so it seemed only logical that the preceding industry used the same freehand technique, but in a 'lower' version. There are of course very clear differences between real Clactonian and simple Acheulean flakes and some differences were most certainly noted: the Clactonian flakes were often thick and the angles at which they were struck were steeper than in the Acheulean (Breuil, 1932, Cubuk, 1976, Franssen & Wouters, 1979a). But everybody was so convinced that the Clactonian preceded the Acheulean that these differences merely confirmed the 'primitive' character. The steep angles, the thick and crude forms and the simple or even absent striking platforms all seemed to point to less controlled blows by less skilled 'primitive' hominids. This wishful retrograde analogy reduced the Clactonian to merely an Acheulean without hand-axes. So when Bosinski (1995) expressed the general consensus that there was no fundamental difference between industries with and without hand-axes, it became very easy to get rid of the 'Clactonian question' by dismissing the Clactonian industry.

When you know the true nature of the differences, these become impossible to deny. For instance when we quickly turn the leaves in Roe (1981), the drawings of Clactonian artefacts on pages 69, 139 and 144 immediately stand out as non-Acheulean. Instead the angles and depth of the negatives on the cores look exactly like the Dmanisi specimens. The flakes also look much more like the Dmanisi flakes than like simple Acheulean flakes. And flakes made on a hard anvil show non-CF signs. A frequent feature in Clactonian flakes is the double cone, which also frequently occurs in experimental oblique bipolar flaking. But the differences between the Acheulean and Clactonian toolkits are not limited to the cores and flakes. The best known Clactonian tool-type is the bill-hook (figure 11). Non-bifacial choppers like pointed and chisel-edged choppers are frequent in the Clactonian toolkit. There are bipolar proto-hand-axes (Wymer, 1968, Cubuk, 1976, Franssen & Wouters, 1979b), Abbevillian hand-axes and Tayac-points. When large nodules of good quality flint were used as raw material, the Clactonian toolkit was dominated by oblique bipolar flakes struck on a soft floor (a technique that can result in CF flakes). But when medium sized river cobbles were used as raw material we see more pointed choppers and Abbevillian hand-axes. Figure 14 shows an example from the Berg & Terblijt Clactonian. At its top this specimen is widest from 'left to right', as we can see in both top right drawings. At its base however it is widest from 'dorsal to ventral' side as we can see in the lower left drawing (and in the photo). Clearly this tool-type was made without bifacial mental template. The steep secondary trimming near the top suggests a scraping function in this specimen. The top was resharpened by a spall (left top drawing). Flat-

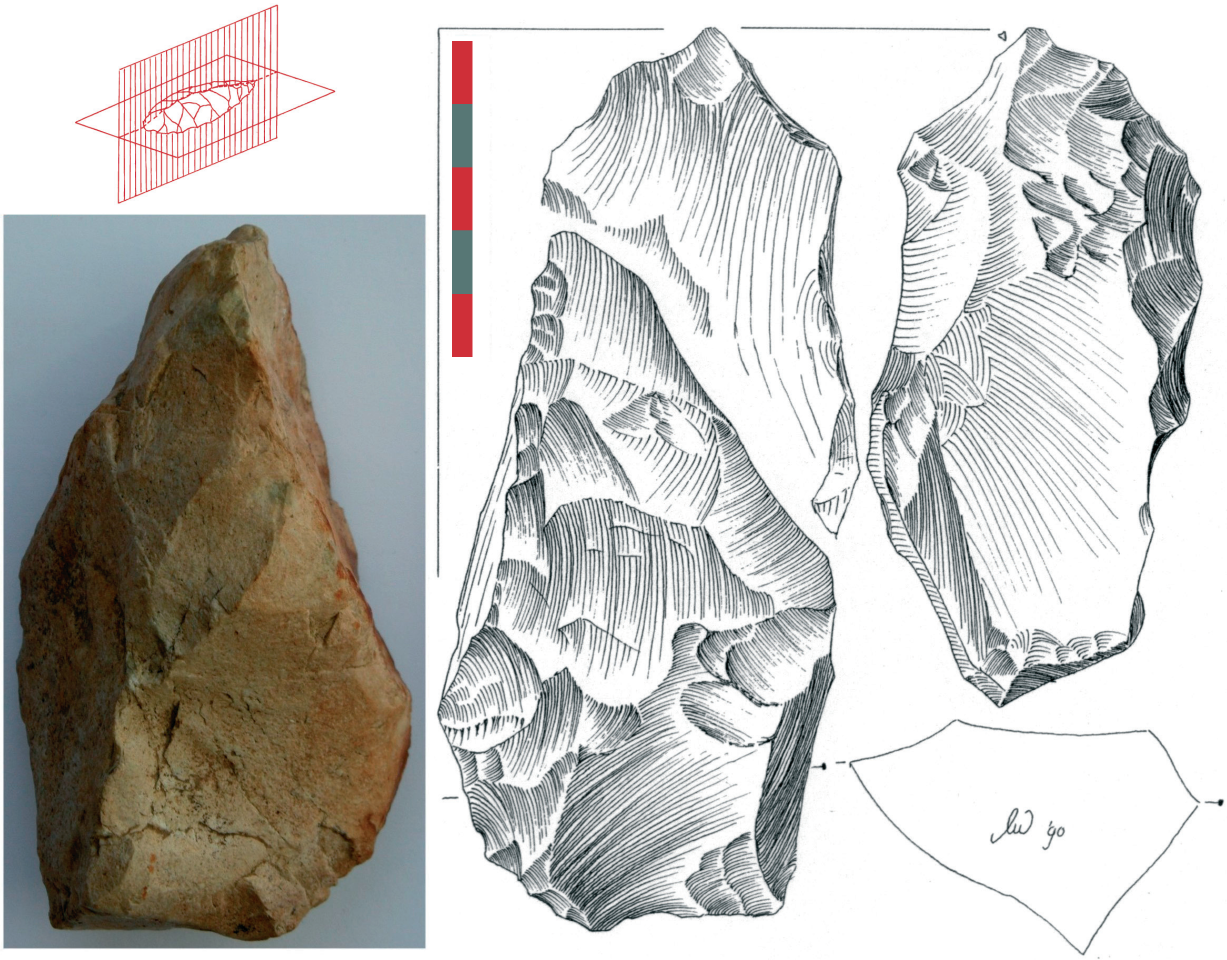


Figure 14: Abbevillian hand-axe from the Clactonian from Berg & Terblijt. The red insert top left shows the concept of volumetric symmetry in hand-axes: the bifacial mental template and volumetric symmetry can be recognized. The Abbevillian tool is very different, it has a multitude of facets instead of a flattened bifacial shape, there is no volumetric symmetry. These Abbevillian tools are more closely related to bipolar pointed choppers so the term hand-axe is inappropriate.

tened Abbevillian hand-axes with a cutting function (as mentioned by de Heinzelin, 1962) do exist but in general the tool-type is closer to a large pointed chopper than to a hand-axe.

5.3 Tayacian toolkit

The lower layers of the site la Micoque produced a tradition which was very different from the younger Micoquian (Rosendahl, 2004) levels. At the suggestion of Breuil this industry was called the Tayacian because the site lies close to les Eyzies de Tayac in the Dordogne. The Tayacian industry could never be properly defined because the technique was not understood. It is therefore not surprising that the Tayacian, just like the Clactonian is now dismissed by most scholars (i.e. Doronichev, 2008). For instance Dibble et al (2006) argued that the Tayacian finds from Fontéchevade were simply flakes with natural damage. And de Lumley and Barsky (2004) withdrew the Tayacian industry from Tautavel as it was postulated by de Lumley et al (1979).

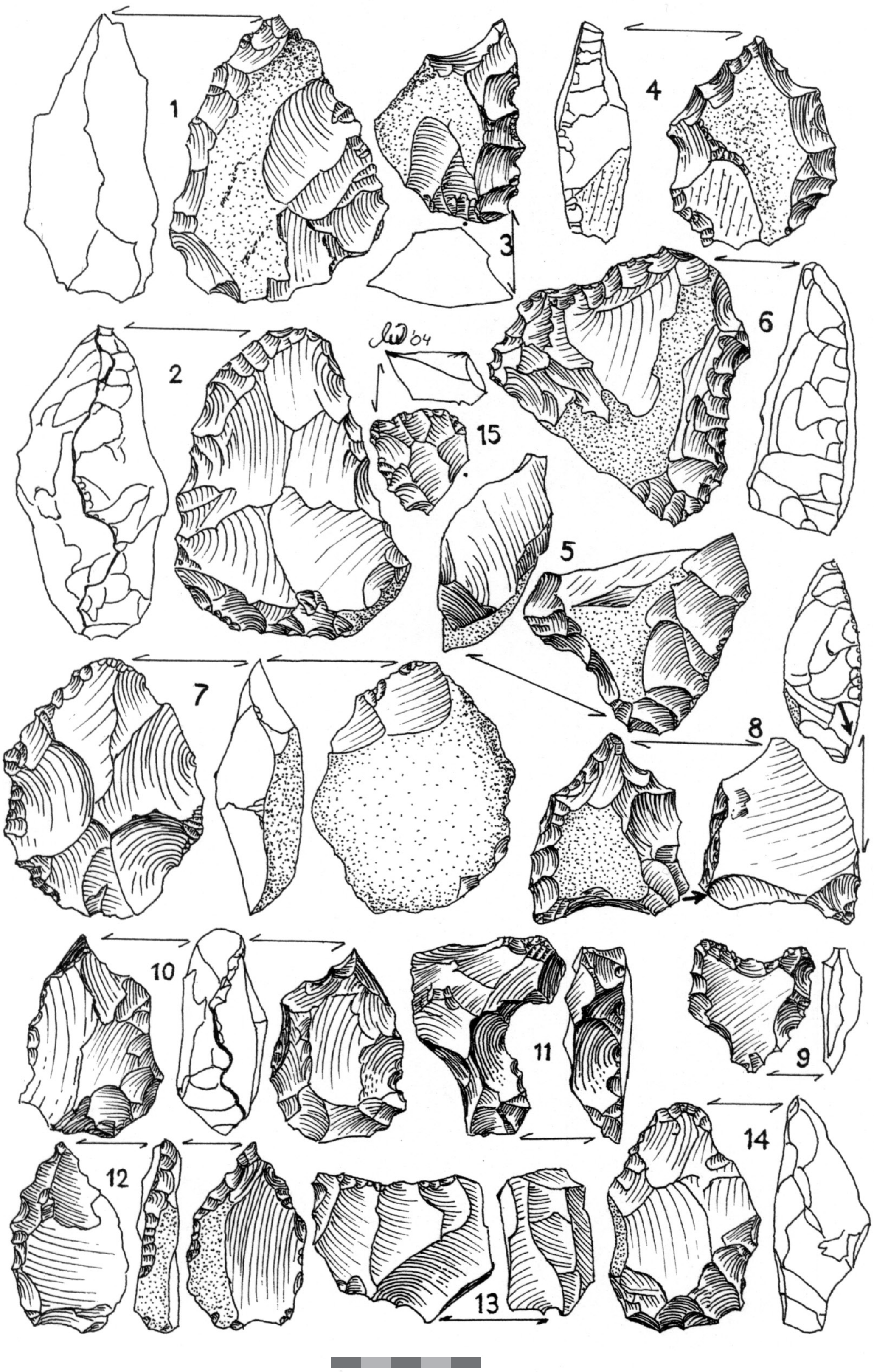
Since there is no accepted definition, I want to describe the Tayacian as: a *flake and core tradition* closely related to the Clactonian, but richer in core-based tool-types such as *Tayac-points* and the flake-based tool-types are rich in *denticulates*. The most typical sites are Bilzingsleben (Mania and Weber, 1986) and Tautavel (de Lumley et al, 1979). The Tayacian toolkit is demonstrated in the figures 15, 16 and 17, based on a site near Mechelen. The hominids at the Mechelen site used both small and large flint nodules and cobbles and also quartz and quartzite. There was enough good raw material to make hand-axes, but these were never made so clearly the group had no bifacial mental template. Instead the toolkit from Mechelen holds simple notches and denticulates and in spite of the presence of good flint quartz pebbles were used. The total toolkit shows a close resemblance to Bilzingsleben. I have demonstrated this by mixing some finds from Bilzingsleben into figure 15. Unless you know which individual tool comes from which site, you cannot tell them apart.

The odd numbers in figure 15 are from Bizingsleben redrawn after Mania and Weber (1986). The even number in figure 15 plus the complete figures 16 and 17 are from Mechelen. We can for instance compare the Tayac-point number 1 from Bilzingsleben to number 2 from Mechelen or the small pointed scraper number 18 to number 15. I show number 7 because it was diagnosed by Mania and Weber as an important non-standardised-Levallois core (1986 p 43 no. 15). But every experimental flint-knapper knows this is not a repetitive freehand flaking core. If this is at all a core (the flake negatives are very small) it should be diagnosed as a bipolar centripetal core. This tool-type was already known in the Oldowan (Mgeladze et al, 2011). More probably number 7 should be interpreted as a centripetally trimmed hemilith or épannelée (Peeters, 1982). Bilzingsleben is well known for its small flint tools but larger tools are also present; these are made from non-flint cobbles and from bone and antler. Very important for a good understanding of the industry are the bone tools which Mania and Weber (1986) called 'hand-axe-like bone-tools' (faustkeilartige Knochengeräte). The same tools were found in Mechelen, but because there was sufficient raw flint in Mechelen, the supposedly 'hand-axe-like' tools were made from flint. A good example is shown in figure 16 number 16 (and in van der Drift, 2007) and closer inspection of this tool shows that it is a backed knife made on very large bipolar flake. When we now take a new look at the bone tools from Bilzingsleben, it is obvious that these too are knives and scrapers without bifacial mental template. Mania and Weber even tried to see a bifacial mental template in what they called a hammer-stone fashioned like a hand-axe (1986 page 301 'faustkeilartig zugerichteter Schlagstein'). But its flint counterpart in Mechelen (figure 17 number 25 and also van der Drift, 2007) shows this is just a pointed chopper. Even the antler points from Bilzingsleben seem to find their counterparts in Mechelen, for instance the pointed chopper number 21. Non-flint cobbles in Bilzingsleben were used to make heavy cleavers. But these cleavers are not failed tools due to the shortage of good raw material, because we find exactly the same heavy choppers (number 26) and cleavers ('bone-breakers' number 24) in Mechelen made from good flint cobbles. So this comparison between sites shows us that bipolar industries were able to produce the toolkit they desired irrespective of the raw material they could find.

Of course similar comparisons could be made with finds from Tautavel and other Tayacian sites. This demonstrates that the Tayacian is not a failed attempt to make a hand-axe industry from poor raw materials. There can be no doubt that the Tayacian has a specific toolkit concept. Unlike Collins (1976) believed, this concept is not limited to the south and east of Europe. Neither should it be limited to the south because climate belts moved north and south, constantly changing the Pleistocene occupation pattern.

5.4 Pebbletools

Pebbletool industries are spread from the Sahara (Ramendo, 1963) in the south, to the Netherlands (Peeters et al, 1988a) in the north. And spread in time from the earliest Middle Pleistocene in Ca' Belvedere di Monte Poggiolo (Antoniazzi et al, 1988) to the Holstein phase in Neer (Kelderman en van der Drift, 2003). Pebbles were also used as raw material in the Neolithic and all over the world (i.e. in Brasil, Prous, 2009), but the Mesolithic and Neolithic assemblages do not show the typical Palaeolithic toolkit. That makes us wonder how this Palaeolithic specific toolkit became so widespread; as if the Sahara pebbletool 'tribes' sent scouts to populate the Netherlands and as if these 'cultures' kept their identity for almost a million years. This led to both fascination and disbelieve; many came to consider pebbletool industries merely as failed Acheulean. The previous paragraphs have now taught us that the pebbletool industries are closely related to the Tayacian and Clactonian. To understand these close relations we must look beyond the pebble *shapes*. These shapes are determined by the primary forms of the pebbles. Mania was able to demonstrate differences between the core and flake based industry in Bilzingsleben and the pebble based industry in Vértesszöllös, but these differences all result from the raw materials. For instance the steepness of the secondary trimming is influenced by the selected primary shapes, which directly result from the raw material. But the intended techno-functional units were the same in the Tayacian, Clactonian and pebbletool industries. The bipolar toolkit could clearly be made irrespective of the raw material, even a few simple pebbles could to the job. The examples of pebbletools in figure 18 are part of a large assemblage made on Thames flint pebbles from a Cromer beach offshore Norfolk. Working pebbles was often the only option in the Dutch river deltas, this made Palaeolithic pebbletool industries with a toolkit that strongly resembles Vértesszöllös very common in the Netherlands (see examples in Peeters et al, 1988a).



Figures 15, 16, 17: These plates give an impression of the Tayacian toolkit from Mechelen. Some microlithic finds from Bilzingsleben are mixed in with figure 15 (the odd numbers in figure 15 are redrawn after Mania und Weber, 1986) to demonstrate that both toolkits merge into one homogenous group. The tools in figures 16 and 17 are all from Mechelen. The large flint tools in these drawings can be compared to tools made from bone, antler and non-flint cobbles in Bilzingsleben.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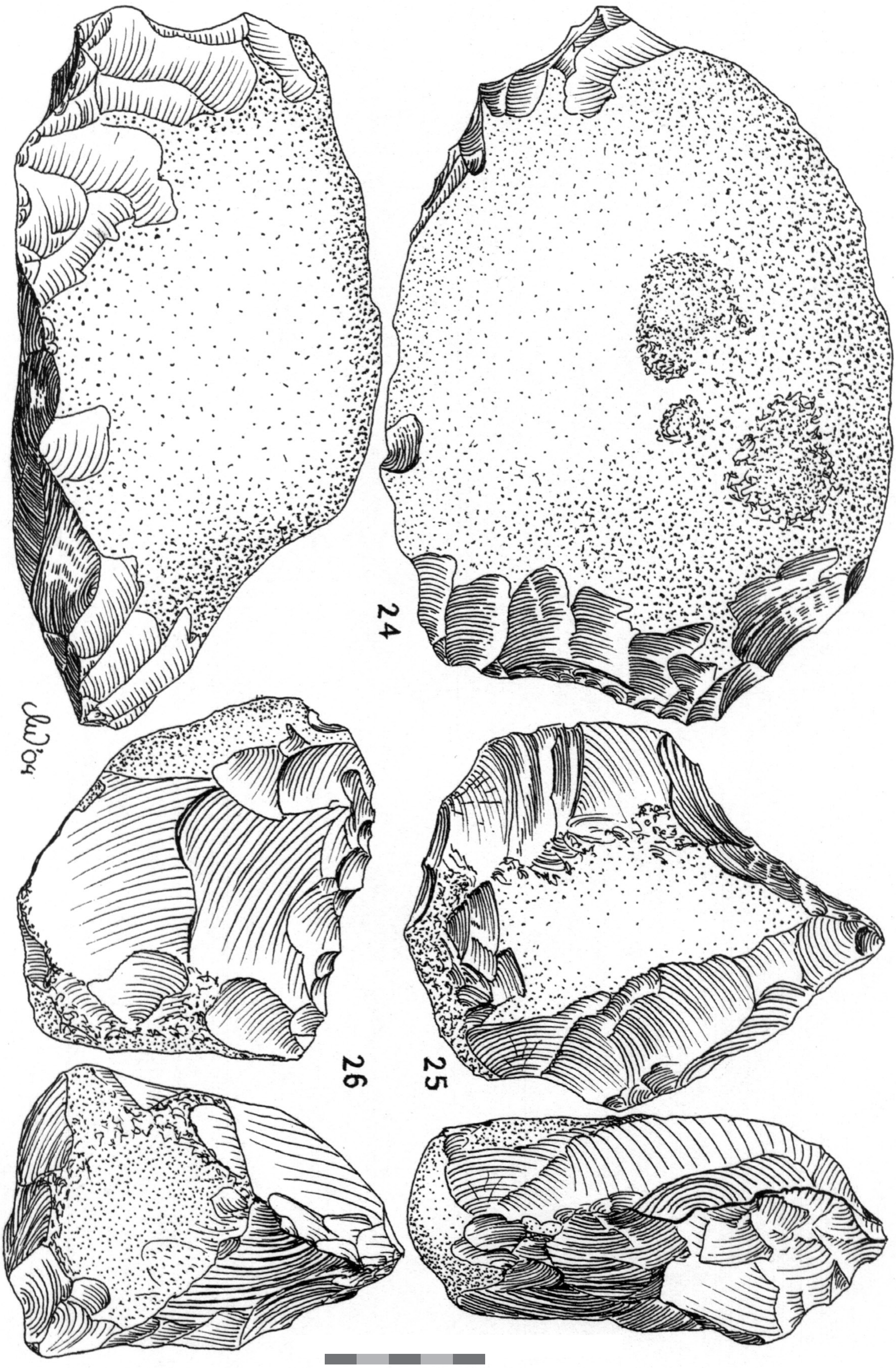
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Figure 18: Pebbletools from offshore Norfolk (photos Ton van Grunsven). At the top two views of a denticulate tool made on a split pebble. Bottom left a pebble segment with invasive flaking. Bottom right a bifacial chopper, these are rare in bipolar industries. Acheulean choppers are modelled through invasive bifacial flaking. But bipolar choppers are not modelled, instead the pebble remains the primary form. Only the techno-functional unit is modified by bifacial secondary trimming.

Figure 19: Upper Acheulean from Wesel (Rhine valley). Out of need for raw material, the group had to use poor quality medium sized volcanic cobbles. Top rows: a selection of the best hand-axes with zigzag cutting edges. Bottom row: on the left a Levallois core and two scrapers.

6 Discussion

6.1 Why

The first question in reaction to the bipolar toolkit concept is 'why'. Why; for what reason would Palaeolithic groups use bipolar techniques as their primary reduction strategy? It seems to go against logic because the freehand techno-complex offers so much more control and more options (figure 8). So if evolution is about constant improvement, we should expect this lesser controlled technique to disappear to the background. This would indeed make bipolar reduction merely a low prestige option for problematic raw materials (Devriendt, 2008, Flenniken, 1979). But Darwin showed that success is not about improvement, instead the *fittest* survive! The freehand technique is unfit for environments with poor raw materials, we can see this in the finds from Wesel in figure 19. The hominids at this site could only find medium size volcanic and quartz cobbles. Surely they must have searched for days and days on their foraging expeditions for better

Figure 20: The photo on the left shows a landscape with dense vegetation. There is little soil erosion so few large cobbles can be expected in the river bed. And the river bed is difficult to access because the vegetation keeps the water levels high. So good raw material cannot be found in this river bed, nor can it be found on land because the vegetation covers the ground. The photo on the right shows an open landscape, the erosion brings large cobbles into a wide river bed that is accessible during most of the year. This situation is ideal for hand-axe makers.

raw materials. But in spite of all the hours lost in the search and in spite of all the effort spent in carefully trying to reduce the thickness of the hand-axes using the bifacial mental template, the end result was really hopeless. Out of hundreds of finds I selected the very best hand-axes for the picture, but they are rubbish. All efforts to make decent flakes, which could be shaped and sharpened by invasive freehand flaking turned out equally disappointing. This can be seen in the Levallois core and both scrapers in the bottom of the picture. This must have been very frustrating, figure 19 clearly shows *the freehand technique was unfit for this raw material*. Just imagine having to make such rubbish tools for the next hundred generations. Fathers would not be able to teach their sons how to make the correct toolkit, therefore the social memory of the group could not sustain the freehand techno-complex. After a few generations the survival of this group was really threatened. We also see such rubbish hand-axes made from limestone pebbles in the C2 and C3 ensembles in Lazaret (Moncel, 2001) and there are more examples. But overall it is fair to say that Acheulean sites with very poor raw material are rare; the Acheulean simply did not go where the raw materials were poor. Instead we see successful bipolar assemblages in areas with poor raw materials. The 'survival of the fittest' ensured the continuity of the bipolar toolkit concept, because it was most 'fit' for the job.

Figure 19 has brought the question 'why' in relation to the raw materials. But contrary to what you might expect, finding raw materials is not simply a matter of geology. To understand this we must look at the Hungarian Által-ér valley with the pebbletool site Vértesszöllös. Everybody that visited the site has seen the Szelim cave high above Tatabánya, both sites are very close to each other. The Jankovichian culture left beautiful leaf shaped freehand tools in the Szelim cave, this group had no trouble finding good raw materials. So why were the hominids in Vértesszöllös unable to find more than a few pebbles? This is explained in figure 20. The photo on the left is the front-page of a book by Dobosi, it shows the present-day Által-ér valley. In this landscape you cannot reach the river bed because the water level is always high. And you cannot reach the ground because the ground is covered by vegetation. So finding any raw material is virtually impossible in the present situation. The photo on the right in figure 20 shows a very different landscape. This is an artificial landscape; a floodplain made in the Meuse valley as a project to regulate the flow of the river. What you see is a riverbed with little vegetation and much eroded material, containing many large cobbles. The picture gives a good impression what the natural riverbed looked like during the Saalian. Large cobbles eroded upstream because there was little vegetation and these were washed into the valley during floods. But most of the year the water level was low, so hominids could walk in the cobble-littered riverbed and simply select the best raw material. This raw material enabled the Upper Acheulean (Markkleeberg tradition) to populate the Netherlands during the Saalian.

So figure 20 teaches us that finding raw materials is determined by the ecological niche. Freehand groups needed good raw materials, these could be provided by eroding mountains, by the sea or wide riverbeds. Wide riverbeds with little vegetation are found in open landscapes (savannas and steppes). Bipolar groups were less dependent on raw materials so they could live in areas with less erosion and more vegetation. The independence of large cobbles enabled them to populate warmer more fertile river deltas. And they had a preference for park-type landscapes, Buxus pollen is often present in bipolar toolkit sites.

6.2 Bipolar toolkit concept

The bipolar toolkit begins to make sense when you understand the link between the raw material and the vegetation. Instead of just a low prestige technique it turns out as a complete specialized concept. Hominids were living in specialized habitats with specialized raw material and foraging strategies, using specialized tool-types. The cutting edge efficiency of hand-axes is often praised, but the bipolar toolkit concept had another kind of efficiency. The hominids increased their efficiency because on their foraging expeditions they could simply focus on collecting food. Unlike the freehand groups they *did not need to drag stones along*, because they knew that at the end of the day there always were a few pebbles that could do the job. So the bipolar toolkit groups clearly were 'the fittest' in vegetated landscapes because of the raw material strategy.

At the same time though, the bipolar toolkit also turned out to be the 'fittest' in vegetated landscapes because of its tool-types! Foraging hominids in open landscapes were constantly at threat from large carnivores and scavengers, so they needed very fast butchering tools: provided by the longest acutest alternating zigzag cutting hand-axes. This is why the LCT's developed into the Acheulean on the African savannas. Hunter gatherers in more vegetated landscapes on the other hand had much more contact with the vegetation and used it more. Not only in the form of collecting tubers fruits and nuts. But also as tools such as digging and throwing sticks, defensive and offensive spears, traps, baskets and nets. The less acute choppers and scrapers, denticulates and notches that are part of the bipolar toolkit are actually really handy for working wood and plant fibre. The bipolar toolkit was ideal for pioneering societies in warm vegetated landscapes, this enabled the Oldowan to spread over Eurasia in the warm Tiglian phase. In cold climate phases the landscapes became open and the hominids had to withdraw to the south. In the Middle Pleistocene European hominids had become sufficiently adapted to survive at the edge of the colder dry mammoth steppe, so finally the freehand hand-axe traditions were able to populate Europe as well. But during warmer more vegetated phases the bipolar groups again got the upper hand; they had the tools to do the job with the raw materials that could be found.

Please keep in mind that we are explaining preferences; there is no complete black and white contrasts between both toolkit concepts. Of course freehand groups used spears and of course bipolar groups used good flint. The Clactonian industry for instance shows that large bipolar flakes were made from high quality flint. So when you add that the Clactonian and Acheulean are sometimes found in a similar environment using similar resources (Waechter, 1976) you wonder again about the 'Clactonian question'. Why did the freehand groups not crowd the bipolar Clactonian out? Perhaps because it was necessary to spend much time in areas where good flint was unavailable. Imagine that groups used good flint in Clacton on Sea, but these same groups needed to live on pebble beaches part of each year, where they could only use Thames gravel. Than perhaps the pebbletools in figure18 were made by the same Clacton groups. This seems possible because technologically the Clactonian, Tayacian and pebbletool industries were 'fully compatible'. This scenario would of course give the bipolar groups an important advantage over the Acheulean groups.

6.3 The pseudo-artefact debate

Most bipolar fractures are non-CF and this of course draws them into the pseudo-artefact debate. In some cases the matrix provides us with a clear answer. For instance the 'Fagnian industry' was found in a marine Oligocene matrix near Liege, therefore there can be no doubt that the bipolar fractures in the Fagnian are strictly natural (van der Drift, 2010b). The matrix in Dmanisi shows us that the finds are manuport and accompanied by hominid fossils, so this matrix proves that the bipolar fractures in the Oldowan are strictly man made (van der Drift, 2011). This is the reason why I chose to demonstrate the non-CF character of bipolar flakes on Dmanisi artefacts in this paper and I want to thank professor David Lordkipanidze and his team for giving me the opportunity to use the undisputable artefacts from Dmanisi in the debate on bipolar fracture characteristics.

In many cases however the matrix is coarse or disturbed. When this matrix still seems geologically correct, the non-CF finds can lead to much debate. We have for instance seen this in claims for Lower-Palaeolithic finds in the Netherlands. These were supported by Bordes, de Lumley and Mania and presented in l'Anthropologie (Peeters et al, 1988a and Clactonian finds in Peeters et al, 1988b). But at the same time Roebroeks rejected these finds as pseudo-artefacts (Roebroeks, 1990, Roebroeks and van Kolfschoten, 1995). A similar situation was seen in the case of Prezletice (Fridrich 1989), where Roebroeks (1995) came to the conclusion that Prezletice shows no convincing traces of human workmanship. The finds washed into a cave in La Belle Roche (Draily and Cordy, 1997) were also dismissed by Roebroeks and Stapert (1986). And also for the assemblage from the cave of le Vallonet (de Lumley et al, 1988) Roebroeks (1995) believed to be 'dealing with an assemblage that was not modified by human agents'. These uncompromised dismissals have exposed the fundamental flaws in algorithm A and they show the urgent need to replace this by the new algorithm B (figure 2).

It is important to warn against selective collecting. Selective collecting changes the overall appearance of an assemblage, therefore selected forms prove nothing. As shown in figure 2 a large typologically correct group from a site with a low incidence of natural fractures is needed to avoid false positive diagnoses. But more surprisingly selection has also led to false negative conclusions; this is the case with the 'Heidelberger Kultur' from the Grafenrain sands found in the layer of the Heidelberg hominid jaw (Rust, 1956). Rust believed that the 'primitive' jaw was accompanied by 'primitive' tools with steep flaking angles. Steeply flaked tools were therefore seen as typical for the 'Heidelberger Kultur' (Bhattacharya, 1977 figure 9.1). But at the same time steep flaking angles were considered proof for a natural character (Barnes, 1939) and the beaked scrapers which Rust considered the most typical tools had also been called the most typical pseudo-artefacts (Warren, 1923, Stapert, 1975) so dismissal was imminent. But the 'Heidelberger Kultur' also holds finer tools, nowadays a few selected finds are even considered genuine artefacts (Wagner et al, 2007 pp. 276–278). These consist of selected flakes with diffuse bulbs and a point with invasive flaking negatives running from hammer to anvil contacts. With our present knowledge it is clear that both the selected 'primitive' forms and the selected 'nearly conchoidal' flakes actually belong to one and the same Tayacian industry. The Nasenschaber or beaked scrapers for instance would have been accepted without problem if they had been found in Tautavel.

7 Conclusions

If we accept the dismantling of the Clactonian and Tayacian, this leaves the Acheulean as the only Lower Palaeolithic industry and it reduces the Oldowan to a 'pre-hand-axe stage'. In this paper I have shown this is incorrect. The Oldowan has a separate typological basis and in Africa it evolved into the Developed-Oldowan. In Europe the Oldowan evolved into the Clactonian and Tayacian. These industries differ typologically from the Acheulean, as Breuil (1932) and Leakey (1979) already showed. But this paper does more than confirm what Breuil and Leakey already showed; it shows *the technological background for these typological differences*. The basic difference lies in the choice for either freehand flaking (Acheulean industries) or *oblique bipolar flaking* (Oldowan and its successors). These two basic technologies have led to two 'parallel developmentlines'. Bipolar industries preceded the Acheulean and also developed contemporary with the Acheulean-Mousterian-line keeping their specific characteristics. The bipolar reduction strategy could be used on poor quality raw materials. The combination of technique, toolkit and raw materials can be linked to landscape and climatic preferences. I have named this *technique-toolkit-material-landscape-climate-complex* the *'bipolar toolkit concept'*. The bipolar toolkit concept is therefore to be added as a separate category in the partitioning system of the Palaeolithic (figure 1). Now that we understand bipolar technology leads to non-CF fracture patterns, the determination algorithm for Palaeolithic assemblages also needs to be adapted (figure 2). Both these changes lead to an improved partitioning system of the Palaeolithic and bring a better understanding for many Palaeolithic industries. The changes furthermore lead to a better understanding of the migration processes, time schedules and development lines in the Palaeolithic era.

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