Bipolar techniques in the Old-Palaeolithic.

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CHAPTER 1: FREEHAND FLAKING

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A PHYSICAL EXPLANATION
For the casual observer it might do, to simply say that flakes are shaped by strike-waves that travel through the core. But for a good basic understanding of lithic techniques, it is essential that we take a closer look at the actual proces that “ruptures” the stone. I will attempt to explain this proces in isotropic material. What is meant by isotropic? Some stones (for instance slate) have layers that facilitate rupture (splitting) in a specific direction. In such stones it is difficult to control rupture in other directions. That is why prehistoric hominids most often preferred stones with a fine grained and even structure, such as quartz, quartzite and especially flint. We call these finely structured stones (more or less) isotropic.

To visualize the rupture, you have to pretend that the isotropic stone consists of very many small units. Not crystals or molecules, but purely hypothetical units that we can visualize as small balls or spheres. I call these the structural units because they are all characterized by the same hardness and elasticity, so all units have the same structural properties. We are all aware of the fact that stones are very hard, they are inelastic, if you squeeze stones you do not see any deformation. A hammerstrike nevertheless squeezes the structural units that lie in the line of the external force. Think of it these units as tennisballs that are hit by the racket; the structural units become compressed or flattened in the direction of the force. This proces of deformation of the structural units is called STRAIN. When the structural unit is flattened, it still keeps the same volume, the same mass, so it must expand to the sides. The result is that the shape of the hypothetical structural unit changes from a ball to an ellipsoid.

That was easy, the difficult part is to understand how the structural units interact. This is visualized in figure 1. You see in figure 1 that an external force (arrow) is compessing one structural unit. This compessed structural unit presses on the units below it. And these on their turn press on the next layer of structural units. With each layer more structural units become involved, the result is a compressed cone. Gradually the compressed units inside the cone, are pulled away from the units outside the cone that are not compressed. And as hard as stone can resist compressive forces, it is very brittle when pulled apart. So the glue between the structural units gives way exactly along this borderline between compressive and pulling forces. The conical shape that you see occuring in figure 1 is the most important feature for the understanding of freehand flaking. In physics this cone is called the “NEUTRAL CONE”. Neutral might seem a strange name for the place where the strain is so great that the stone ruptures. But the word neutral was chosen to emphasize the fact that the pushing forces are found on the inside of the cone and the pulling forces are on the outside the cone.

Nice theory you might say, but in real life, it seems that

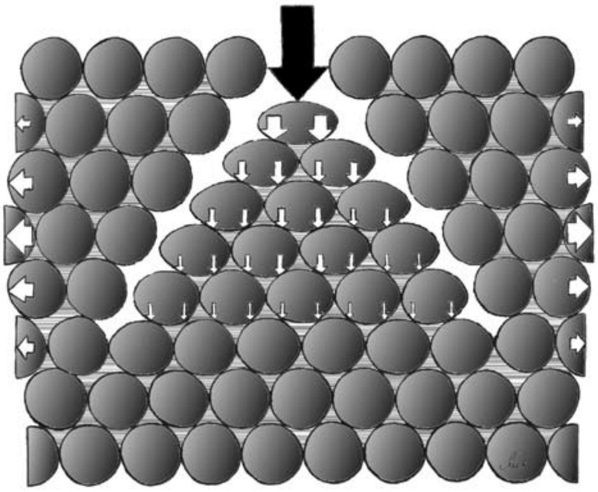


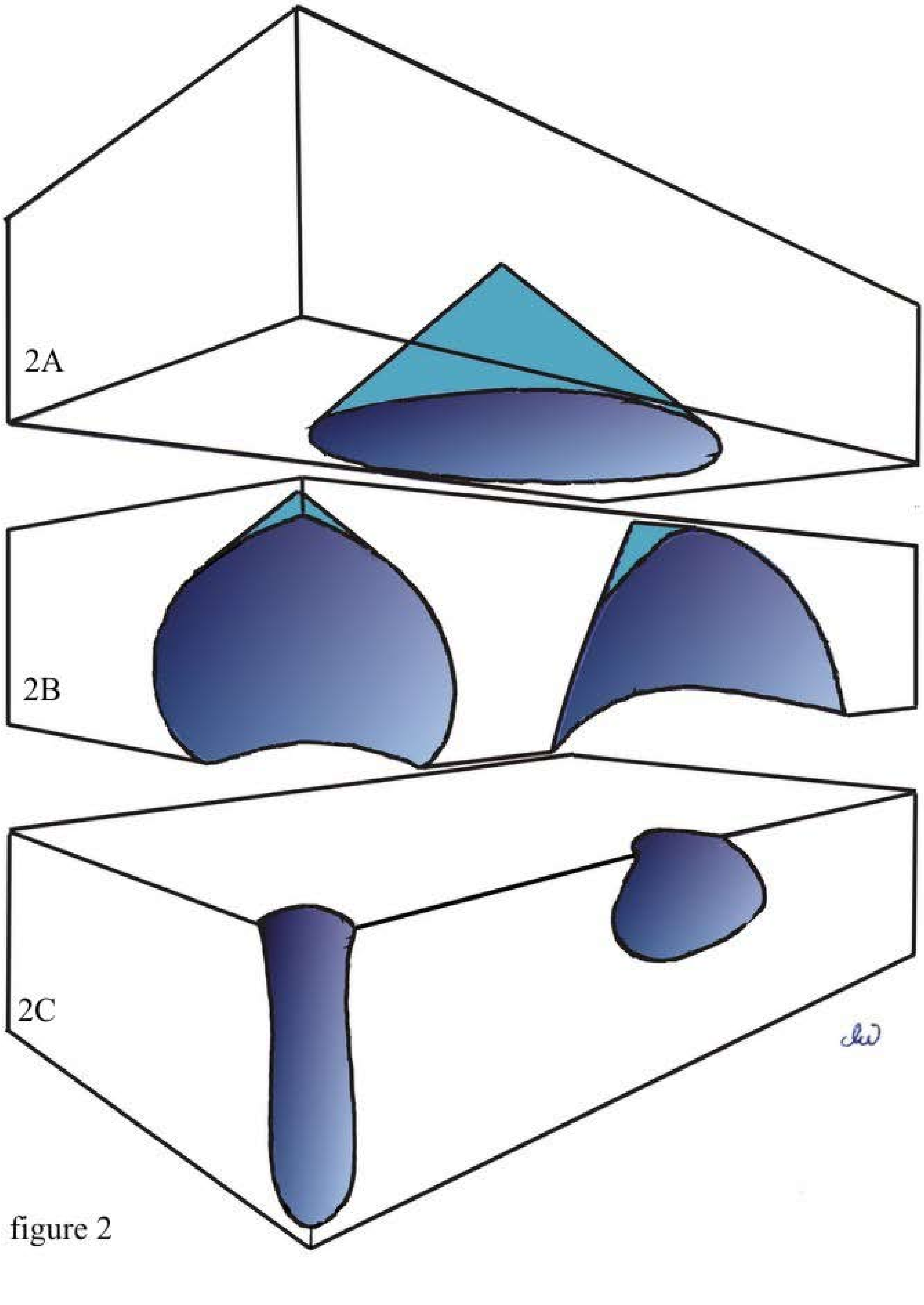
figure 1

FREEHAND FLAKING A PHYSICAL EXPLANATION
Figure 1: strain pattern in structural units.

you hardly ever find conical fractures. So why is this? That becomes clear if we take another look at figure 1. The second layer of structural units that get compressed, is twice as wide as the first layer. As a result the force is spread in a surface that is 4 times as big (the surface of a circle is pi times radius square). So as the rupture progresses along the sides of the cone, the strain that drives the rupture becomes exponentially lesser and lesser. As a result of the weakening strain, most conical ruptures rapidly come to a dead end. We see such dead-end fractures for instance covering the complete surface of neolitic cores that were used to peck millstones, to roughen the surface so the wheat didn’t slide off. Toolmakers were not at all intersted in small dead-end cones, they wanted large flakes, so how did they turn small cones into large flakes?

PLACING AND DIRECTING THE STRIKE
The answer is simple, by placing and directing the strike in a way that the largest part of the cone falls outside the stone. I have explained this further in figure 2. Let us first take a look at 2A. What happens here is actually the same as figure 1; the strike is placed on the centre of the core and directed to the heart of the core. The physics law by Hooke tells us that the elasticity equals (the surface times the change in length) divided by (force times original length). The elasticity of the material is a constant factor. So if we want the force to produce more strain (change in length) this is only possible by reducing the surface that the force works in. This cannot be done by changing the opening-angle of the cone because the opening-angle is a constant, defined by the material. In flint this angle is calculated to be 120 degrees. But in reality flint has a structure with microscopic cavities, you could say that it resembles a sponge. These cavities reduce the actual measured value to an average of 100 degrees. Because the angle of the cone is defined by the raw material, we may also call this neutral cone the “idiomorph cone”.

As changing the properties of the material is impossible, the only possible way to reduce the surface is demonstrated in figure 2B. We now place the strike near the edges of the core and direct the cone to the outside. As a result the pushing forces inside the neutral cone work in a much smaller surface and this of course leads to a larger deformation (or strain, or change in length). To understand how the cone sections that we see in 2B



PLACING AND DIRECTING THE STRIKE Figure 2: 2A conical train pattern, 2B cone sections, 2C blade and flake.

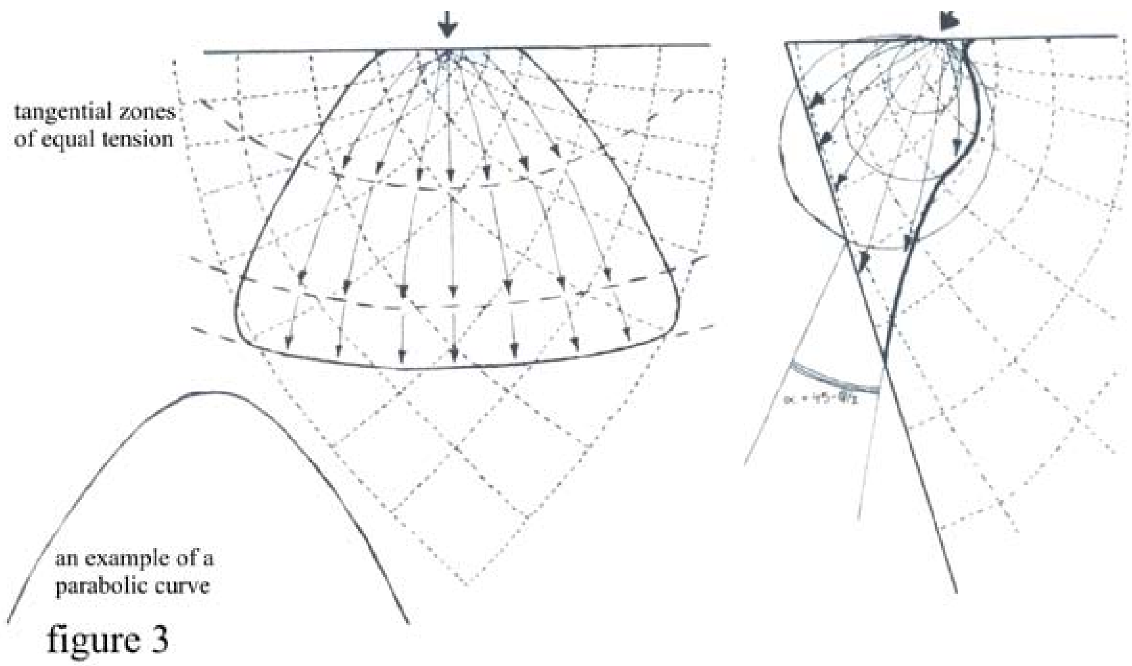


Figure 3: crossing tension zones produces a parabolic fracture.

actually produce the conchoidal fractures that we see in 2C we have to return to figure 1. If the strain flattens the structural units, these units must expand sideways. So the material around the cone will have to give way sideways. This is shown in figure 1 by the small arrows pointing sideways. Returning to figure 2 we see the influence of the sideways stretch because the fracture does not simply look like a section of a cone. Instead we see the smaller conchoidal fractures in 2C. A blade shaped conch is produced when the strike is at the edge and a shorter flake when the strike is given at a side.

This transformation of a cone section (2B) into a conchoidal shape (2C) does need some extra explaining. Horace Bertouille (1989: théories physiques et mathématiques de la taille des outils préhistoriques. Cahiers du quaternaire no 15. Paris) does this in what I believe to be a rather theoretical way. He tells us that there is a tension at a certain distance from the striking point. This tension zone is extended at a 90 degree angle into the core. The tension zones bend and cross eachother at again 90 degree angles. The actual fracture travels trough these zones at a 45 degree angle following the maximal tangential tension. Bertouilles explanation is mathematically correct and it is demonstrated in figure 3 how parabolic fracture lines can be constructed in cores that have an ideal shape. But for practical purposes and an easy explanation I prefer to base my own ideas on the distribution of the deformational forces, as I have shown in figure 4.

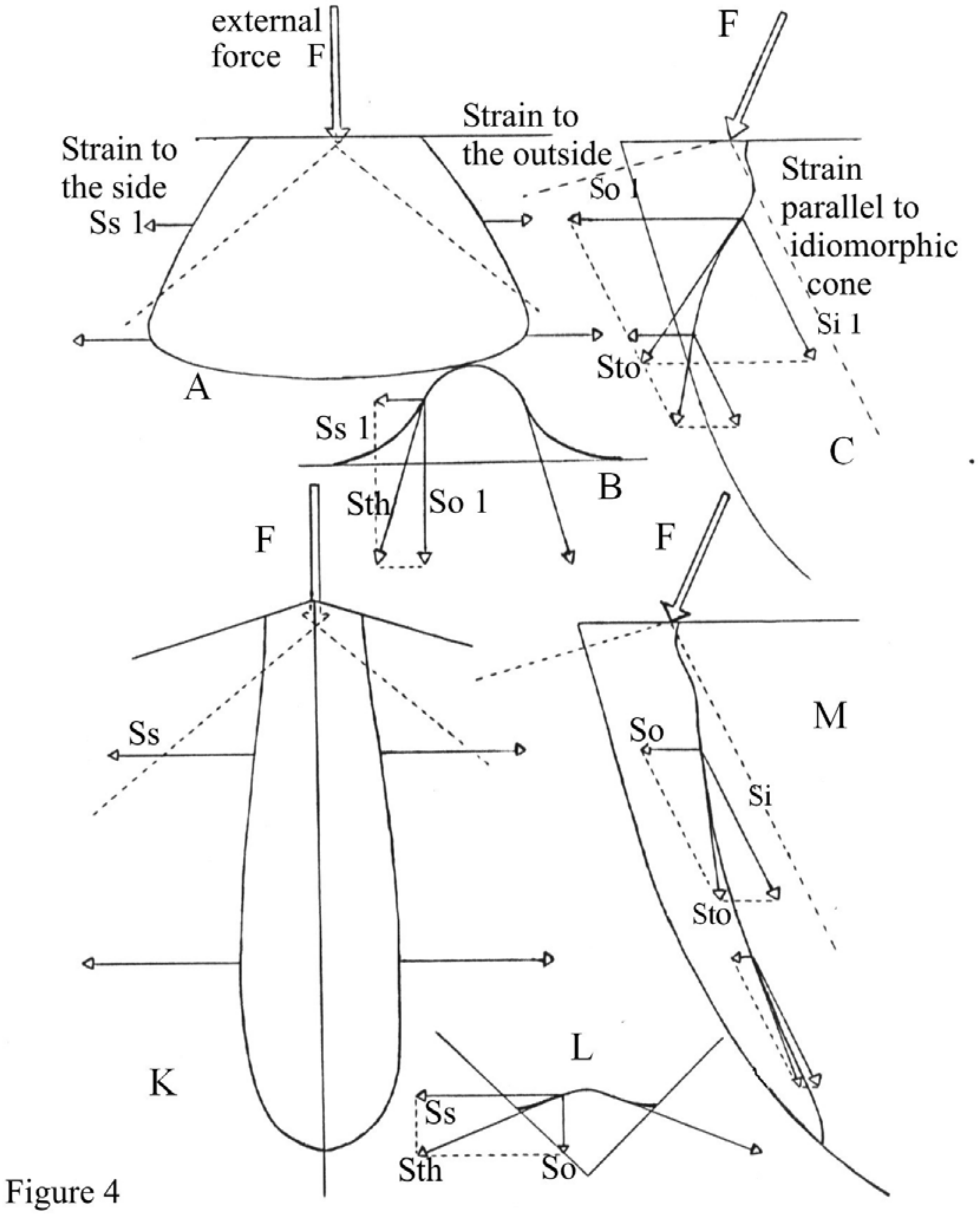
BLADES AND FLAKES

Figure 4 shows us a flake in frontal view (4A), seen from the top (4B) and from the side (4C). And also a blade, seen from the front (4K), the top (4L) and the side (4M). Every action begins with an external force F, that causes vertical stress leading to compression or strain. As we discussed above, vertical compression depends on lateral stretching. This means that vertical strain and vertical propagation of the fracture are greater when the fracture is closer to the sides of the core. This explains the difference between a flake and a blade.

The differences between flakes and blades are best compared in top view, so we should compare 4B to 4L. In 4B there is only very little streching possible to the left and the right sides (Ss) because the outside of the core in these directions is far away. Since there is very little stretching to the sides, the horizontal compression must lead to very much stretching to the frontal outside or reduction face (So) of the core. As you can see in 4B I have visualized this horizontal strain by drawing vectors (arrows). The direction of the vectors symbolises the direction of the strain and the length of the vector symbolises the strength or size. Adding up the very small horizontal strain to the side and the inherently large strain to the front gives us the total horizontal strain (Sth). In any given point of the fracture line this total horizontal strain forms the tangent, meaning that the arrow points in the direction that the rupture (or fracture) line is taking at this point. Understanding this, we must now compare 4B and 4L. Here in 4L the frontal side of the core shows an angle or edge and this of course greatly facilitates stretching to the sides. If so much more of the horizontal strain (Sth) goes to the sides (Ss), far less stretching to the front (So) remains.

If you understand this, we can go to the side views (4C and 4M). In these drawings, the neutral or idiomorph cones are shown as dotted lines. In figure 1 we explained that the external force leads to a maximal (compression and pulling) strain and rupture along the sides of these cones. We visualize this strain by a vector parallel to the side of the cone, and call this the idiomorphic strain (Si). Now it is easy to construct the direction that the rupture takes by simply adding up this idiomorphic strain vector (Si) and the horizontal strain to the front (So). This total strain vector (Sto) is again the tangent, showing the direction of the rupture. It is now very obvious, that an external force of the same size and direction, can create very different ruptures depending on the shape of the core. If the core permits little stretching to the sides the compression must lead to much stretching to the front producing a short rupture or flake (4ABC). An edge or rib facilitating sideways stretch and therefor leads to a longer rupture or blade (4KLM).

Now you have a basic understanding of freehand flaking; the most important lesson you have seen is that the fracture will always try to follow the outlines of the core. Bertouille explained this with tension zones and ideal pa-



BLADES AND FLAKES Figure 4: strain vectors in a flake (ABC) and blade (KLM).

rabolic isostatic core shapes. I explained it with deformation vectors. Prehistoric hominids experienced it, leading them to a concept (idea, mental template) that they could shape a stone by peeling of flakes and blades along the outlines of the core. This immediately lead to the shaping of the handax and in a later stage lead to the concept that better flakes and blades could be made by manipulating (shaping) the outlines of the core. This concept is called prepared core technique, the Levallois technique is the best known prepared core technique.

CHAPTER 2: BIPOLAR BREAKING

THE FORCES

This basic understanding of freehand flaking, teaches us that freehand flaking does have its limitations. It is for instance impossible to peel off flakes from a round core (i.e. a river pebble) because it has no striking plane, no reduction face, no edge or rib. And a freehand blow directed to the centre will be too weak to break the core, at its best it will produce a dead end cone. That could certainly prove to be a great problem for early hominids living on the edge of a river, when all they find at the river banks are rounded pebbles. Let us take as an example, a round pebble with a diameter of 1 cm. Take this pebble in your free hand and strike it with a hammer weighing 0.5 kilo at a speed of 10 meters per second. To give you an idea of what happens, we can make a simple calculation. Our calculation is physically not correct (we should use formulas for the impuls and impact of colliding bodies) but my simple calculation is easier to understand. The pebble is so small that on collision, it hardly slows the hammer down. As a result your hand gets most of the blow! Say that it takes 0,25 meter to stop the hammer, than we part this distance by the mean-speed and you find this proces takes 0.05 seconds. That makes for a deceleration of 10 m/sec per 0.05 seconds, so this equals 200 m/sec.square. The force this produces can be

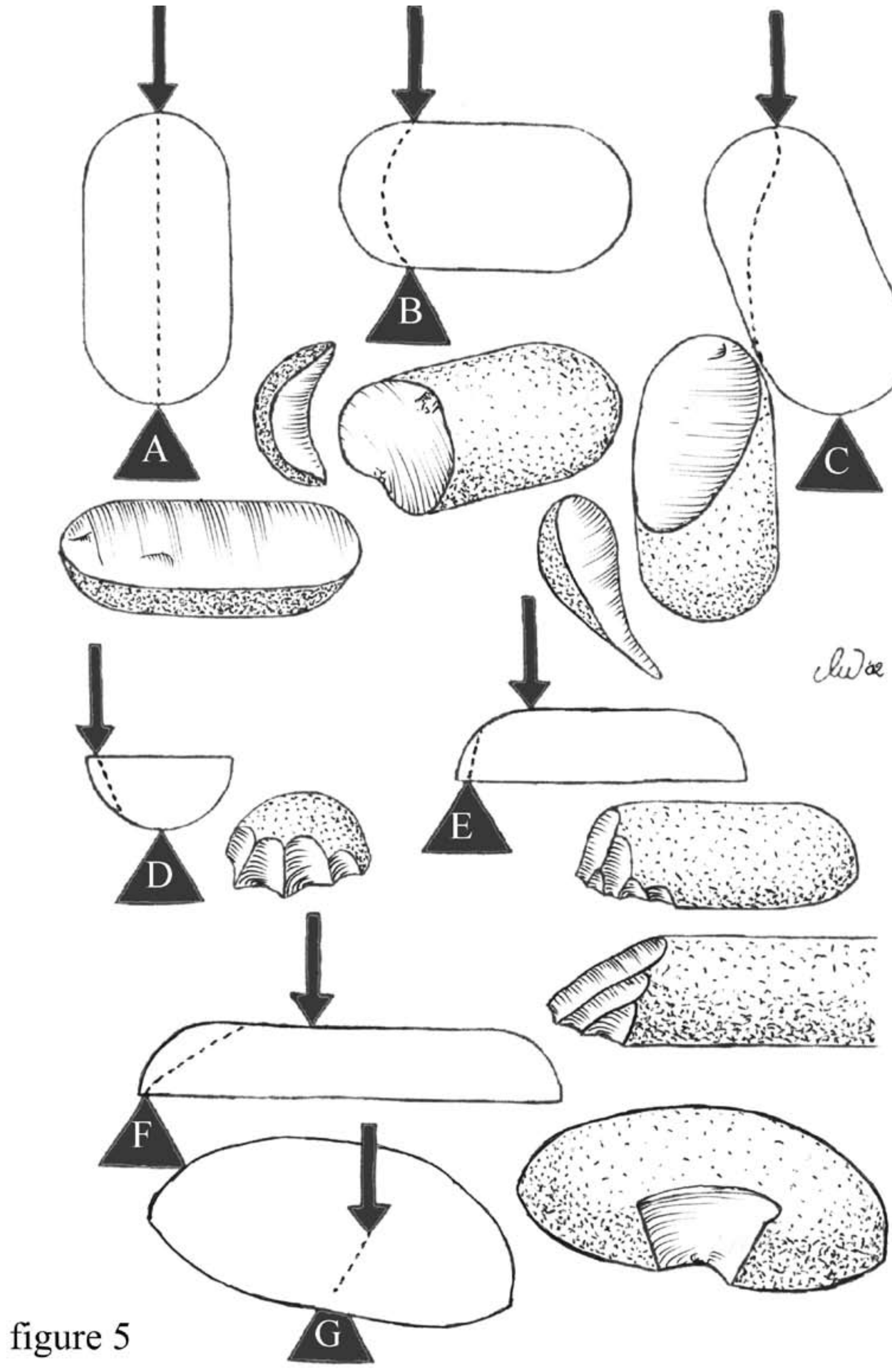


Figure 5: bipolar techniques A and B straight, C oblique, D and E retouching, F contre coupe, G notching.

calculated as mass times deceleration, so this equals 100 Newton. This is actually the same as a bucket of water resting on the pebble so the pebble will not break! In free collision, the small pebble will only break when it is struck at about the speed of sound! It is very clear now that freehand breaking and freehand flaking of a small round pebble are humanly impossible.

The finding that freehand techniques cannot break or flake small round pebbles, does not mean that such stones cannot be worked. It only takes a different, more adequate technique; we simply must put the pebble on an anvil before we hit it. Let us repeat exactly the same hammerstrike (0,5 kilo 10 m/sec) in this new situation. The anvil will not give way more than 0,001 meter, and therefor the deceleration is much faster. It takes only 0,0002 seconds and measures 50000 m/sec.square. Decelerating 0,5 kilo like this, produces 25000 Newton. This is actually the same as 2500 kilogramforce or 3 small cars resting on the pebble. So in comparison with the freehand technique, the force is tremendous. This certainly will break the pebble, it might even crush it.

These calculations confirm that the use of an anvil allows for lower striking speeds or smaller hammers to be used. That makes the simultanious use of hammer and anvil a

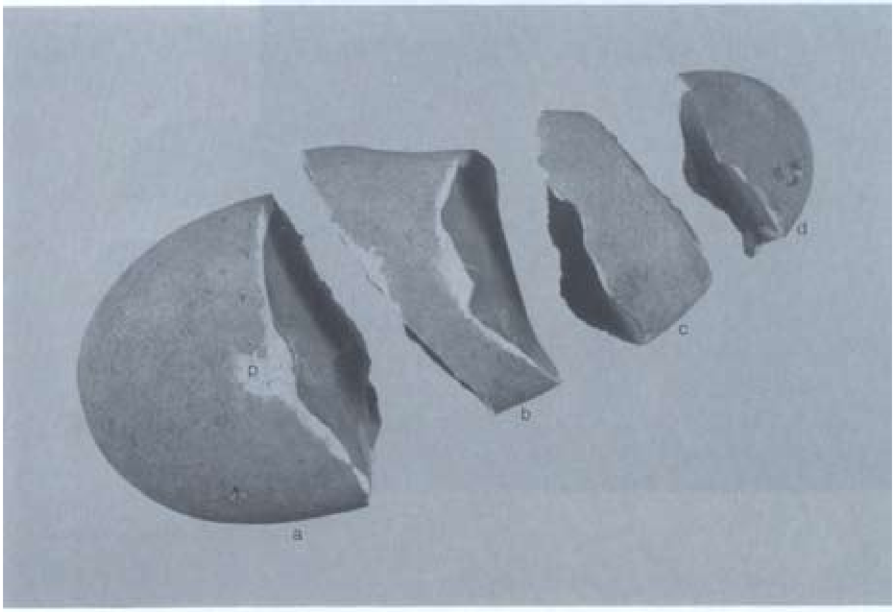


Figure 6: experimental pebble slicing.

very safe and very adequate technique. We call this the bipolar technique, because there are forces working in the pebble from two opposit sides.

PEBBLETOOL CULTURES
The advantage of the freehand technique is that it produce blades and flakes in an effective, reliable, controlled way. Because of the control that it gives, it was the technique of choise for most hominids with access to large isotropic stones. But in the palaeolithic many hominid groups in lowland river delta areas could not find large isotropic stones. Instead these hominid groups had to rely on small pebbles and bipolar techniques. The industries that these hominids produced (for instance Vértesszöllös) are called pebbletool-cultures due to the obvious use of pebbles as raw material. But the role of the bipolar techniques in pebbletool-cultures has hardly been investigated and often denied. We should get a better understanding of the possibilities that bipolar techniques offer, few archaeologists have even recognised that bipolar techniques offer choises. In order to understand pebbletool cultures and related industries we must study the options that the bipolar techniques offered.

STRAIGHT BIPOLAR TECHNIQUE
The first and simplest option is the straight bipolar technique. The straight bipolar technique is also known as axial bipolar technique (F. Diez-Martín). It is also known as nutcracker technique because of the obvious similarities to the way that humans and apes crack nuts. Early hominids must have used the straight bipolar technique to crack nuts and bones for the extraction of marrow.
In the straight bipolar technique the strike is directed straight to the anvil contact point. Examples are shown in figure 5A and 5B. The external force of the strike is visualized by an arrow and the anvil by a triangle. Remembering our figures 1, 2 and 3, the first thing we want to do is look at the idiomorphic or neutral cones. There is a cone originating from the hammer-strike, and an opposit cone originating from the anvil contact-point. The first cone compresses the stone outside the borders of the second cone, so the “neutral” zone of the cone is compromised. The greatest strain in the straight bipolar strike in 5A therefor is no longer simply along the sides of the cones, instead it is found in a straight line between hammer and anvil contact points. On my film “the bipolar toolkit concept” you can see experiments by Ton van Grunsven where he demonstrates that pebbles can reliably be split in two with this technique (provided that the raw material is isotropic). In figure 5A the pebble is placed vertically (F. Diez-Martín calls this vertical bipolar percussion).

In figure 5B the core is placed horizontal (F. Diez-Martín calls this horizontal bipolar percussion). If the strike is placed at the centre of the horizontal core, the fracture will be straight and produce two halves (compare 5A).
In the drawing 5B however, I have placed the strike and anvil contact-point nearer to one side. This brings a very important change; the fracture line will no longer be straight because the horizontal stretching is much easier to the closest outer side of the core. In 5B stretching is easier to the left so the maximal strain is shifted to the left, resulting in a fracture line that is bent to the left. We call this technique pebble-decapitation. Decapitated pebbles show a fracture that is curved in two opposit directions, the fracture is convex from hammer contact-point to anvil contact-point and it is concave in the perpendicular direction. If this straight bipolar percussion is repeated on the decapitated pebble, you will produce a pebble-slice. The fact that László Vértes found pebble-slices in Vértesszöllös, is additional proof that bipolar techniques were used at this site. Figure 6 shows experimental bipolar slicing.

The difference between horizontal and vertical percussion becomes more relevant when very large quartz cores are used (as F. Diez-Martín noted in African sites like Olduvai BK). In large cores from vein-quartz, it is more logic to use horizontal bipolar reduction. In these large cores the distance between hammer and anvil is too great in vertical reduction, such fractures take more force and are less controlled.

OBLIQUE BIPOLAR PERCUSSION
In figure 5C the force is now no longer directed towards the anvil contact point. This is what I call oblique bipolar percussion (and F. Diez-Martín calls non-axial bipolar percussion). This oblique bipolar percussion makes bipolar techniques really interesting. For this is no longer the simple nut-cracker method. This is a clever way to make a sharp edged chopper and a sharp edged flake in one strike! You can see this in figure 5C and in my film “the bipolar toolkit concept”. If we were to split up the strain in figure 5C (just as we did in figure 4), there would be a larger vector pointing from the hammer contact-point to the anvil, and a smaller vector pointing to the left. This

BIPOLAR RETOUCHING Figure 7: Tayac-points are converging denticulates and are most often small (scale 5 cm.) and triangular in cross-section, they should not be compared to handaxes which are smooth edged bifacial large cutting tools.

smaller vector to the left pushes the fracture line to the left. The fracture bends just like in pebble decapitation (5B). But unlike in pebble decapitation, this oblique bipolar fracture will never reach the opposit contact point!!! You can see in my film "the bipolar toolkit concept" that the fracture can also become initiated in the anvil contact point and run towards the hammer, never reaching the hammer contact-point.

It is difficult to distinguish between oblique bipolar flakes and freehand flakes. Oblique bipolar flakes never show any double contact points or double ripple patterns. And smaller differences (i.e. different angle, striking plane, curvature, bulb formation, bulbar scar location) are easily overlooked. This explains why for instance László Vértes mistakingly thought that "No traces indicative of a bipolar technique have been observed." in Vértesszöllös. Just like any freehand flake does, flakes made in oblique bipolar technique show only one contact point, a sharp edge at the opposit side and they have a nearly conchoidal shape.

BIPOLAR RETOUCHING

It is possible to start out with a rounded pebble, break it open with the nutcracker technique and as the broken pieces have striking planes and reduction faces, you can than proceed using freehand techniques. This is actually what D. Mania proposes for Bilzingsleben. I do not believe that this is what happened. In Bilzingsleben there might certainly have been some opportunistic freehand flaking, just like in other bipolar traditions. But the majority of the further shaping and retouching of the artifacts was done in bipolar technique, as shown in figure 5D and 5E. This is proven by the tool shapes (discussed in my film "the bipolar toolkit concept") and the signals discussed in chapter 3. The first reason for bipolar retouching is that anvils proved to be very helpful in working steep edges, it is often still very difficult to shape split pebbles using freehand techniques. But this is not the only reason to use oblique bipolar percussion in shaping and retouching implements, this choise was also greatly influenced by habit, tradition, culture.

We must realise that although hominids do not simply repeat the same motions over and over again like machines, they are creatures of habit. And the repeated and habitual use of bipolar techniques in the initial shaping of pebbles must have trained the hominid mind in understanding the consequences of bipolar reduction. Anvil use was a habit in some traditions! And it goes much further because each step of the production line was part of the integral tradition, from the gathering of pebbles as raw material on the banks of a stream to the next step of bipolar breaking and the following step of bipolar shaping to the final step of the application of the tools. Groups using the freehand toolkit concept had the habit of using freehand flaking on good raw material (often found on open planes and in mountains), most often with the intent of using bifacial reduction to make handaxes (long cutting tools) that were meant for meat and hides processing (from large grazers in open landscapes). Groups using the bipolar toolkit concept often lived where good raw material was difficult to find such as forests and river deltas. They had the habit of using bipolar reduction to make choppers, steep scrapers, deep notches and related tools. In the early Oldowan the choppers were used directly for food processing and this meant that the invention of long cutting tools was an improvement and the decisive step towards the Acheulean. But in the middle pleistocene bipolar traditions in Europe and Asia, the steep scrapers and notches and related tools were meant for wood and bone processing. The combination of stone and wood and bone tools were used to proces food. So the bipolar toolkit traditions had developed a completely different concept of suitable raw material, a completely different concept of tool-shapes and a completely different concept of tool-use. This is actually the reason why I used the word concept in the title of my film "the bipolar toolkit concept". The group or macroband of hominids had a completely different concept in their collective memory than the freehand groups. It was not the simple cracking open of small pebbles (Mania called this Zertrümmern) but it is this complete concept that ensured survival of the group.

All of this certainly means that it is very important that we can distinguish between reduction using the freehand concept and the bipolar concept. For this reason we must study the special signals that are caused by bipolar retouching. The first thing that catches our eye is (as we men-

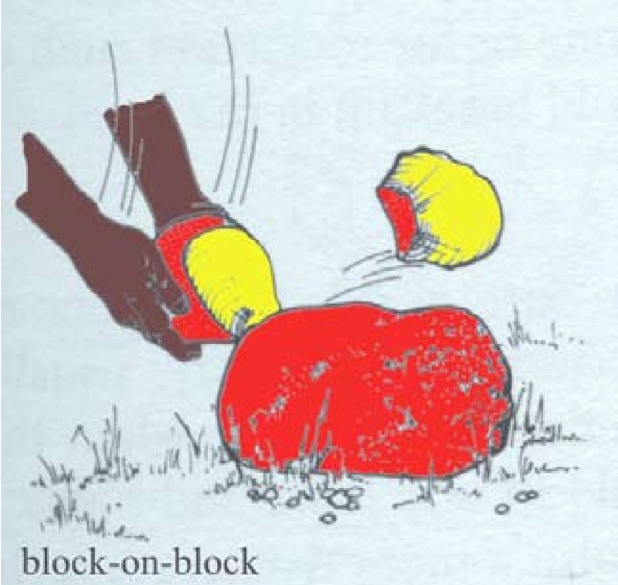


Figure 8: block-on-block is a unipolar anvil technique, it is not bipolar.

tioned before) the angle of the flaking. Freehand flaking is limited to acute angles. This makes freehand flakes ideal butchering tools for hominids that live on large animals. Bipolar traditions.are not limited to acute angles, acute perpendicular and even obtuse angles are all possible depending on where you place the hammer-contact and anvil-contact points. And because bipolar tools were often used for processing of plants and bones, less acute or even obtuse angles did make effective tools.

As we have seen, retouches can be initiated in the anvil contact-point as well as in the hammer contact-point. Figure 5D shows oblique retouches initiated in the hammer contact-point and 5E in the anvil contact-point. Often you can actually change the side where the fracture begins by sliding the contact-points back and forth. Now this makes for a very different concept, a very different understanding of toolmaking than in freehand technique! If you want the fracture to change direction in freehand technique you will actually need to turn the core over. This is an essential step in the development of palaeolithic culture, because it was this repeated turning over of the core in freehand flaking (to see the results of previous flakings, to plan the next flakes and to change direction), that led to the invention of the bifacial tool production in Acheulean style. This relation between turning the object over and over and over again, and the creation of handaxes is demonstrated in my film “the bipolar toolkit concept”. This is a very noteworthy observation, it explains why middle pleistocene traditions without this constant core turning and without handaxes are most often bipolar traditions. And understanding that traditions without handaxes are rather often bipolar, confronts us with the fact that bipolar industries are not limited to pebbletool groups like Vértesszölös, there are also bipolar industries based on oblique bipolar flakes! The most obvious example is the Clactonian. Since the Acheulean and the Clactonian are contemporary and might even occur in similar climate conditions, the old idea that handaxes were not yet invented cannot explain the absence of handaxes in the Clactonian. On the other hand, my idea that the hominids making Clactonian industries had the concept of bipolar percussion does explain all the aspects of the Clactonian. It is easy to explain why the Clactonian was considered to be a simple (pre-handaxe and pre-Levallois) freehand industrie in the past, this mistake was made because it is very difficult to distinguish between freehand and oblique bipolar flakes. And because opportunistic freehand flaking did occur in all bipolar

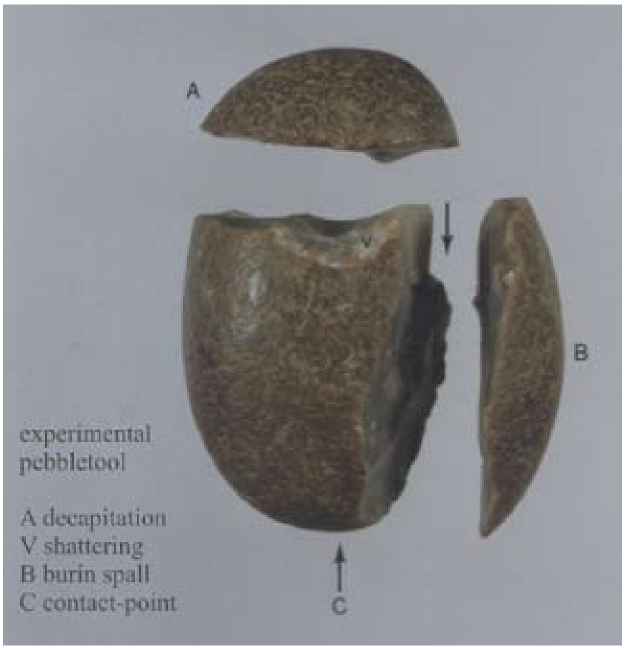


Figure 9: experimental flint pebble burin.

traditions, certainly some of the Clactonian flakes might have been struck from the free hand. Other flakes were struck on the ground without an anvil, but most Clactonian flakes were struck on an anvil. The use of opportunistic freehand flaking does not change the basic fact that the Clactonian was made according to the bipolar toolkit idea, style or concept.

In freehand retouch, the hammer is used to skim a thin sharp edge. The skimming hammer strike removes the protruding parts of the edge. In my film “the bipolar toolkit concept” you can see that the flint-knapper chooses a rib that needs to be flaked (to reduce the thickness of a handax) and deliberately creates a protuberance there before he makes the skimming strike. Than the skimming strike action flakes the protuberance and removes the rib. Because protuberances are removed, the skimming directly leads to a trimming of the edge into a straight edged scraper or knife, certainly when a soft hammer is used. In oblique bipolar retouch, the working concept is that each strike produces one flake. It is possible to make a regular and straight trimmed working edge one flake at a time by careful positioning. But more often bipolar retouch produces a very irregular or even denticulated working edge. You have to realise that bipolar denticulated tools are different from the freehand denticulates, that we find for instance on Mousterian thin-edged flakes or blades. The bipolar denticulates are often made on thick and steep edges, creating prominent teeth like in figure 5D. Such prominent denticulates are for instance well-known from the Tayacian/Tautavelian industry. It should by now no longer come as a surprise that this industry without proper handaxes is also made according to the bipolar concept. Bordes defined the “Pointe de Tayac” as a converging denticulate and de Heinzelin added moreover that these tools were made by macroencoches, which are deep hollow flakings. If we add that these Tayac-points can incidentally be bifacial but are more often trihedral in cross-section, that many are too small to be used as butchering tools and that use wear analysis according to de Lumley often points to use on bone or wood, it is clear that any comparison to handaxes is wrong. Tayac-points are clearly not “miniature handaxes”, they obviously are part of the bipolar toolkit concept.

SPECIAL BIPOLAR TECHNIQUES

Figure 5F shows that oblique bipolar flaking can also produce a very acute flaking angle. This is seen if the

SPECIAL BIPOLAR TECHNIQUES Figure 10: the deep notch is central in Clacton bill-hooks (scale 5 cm.).

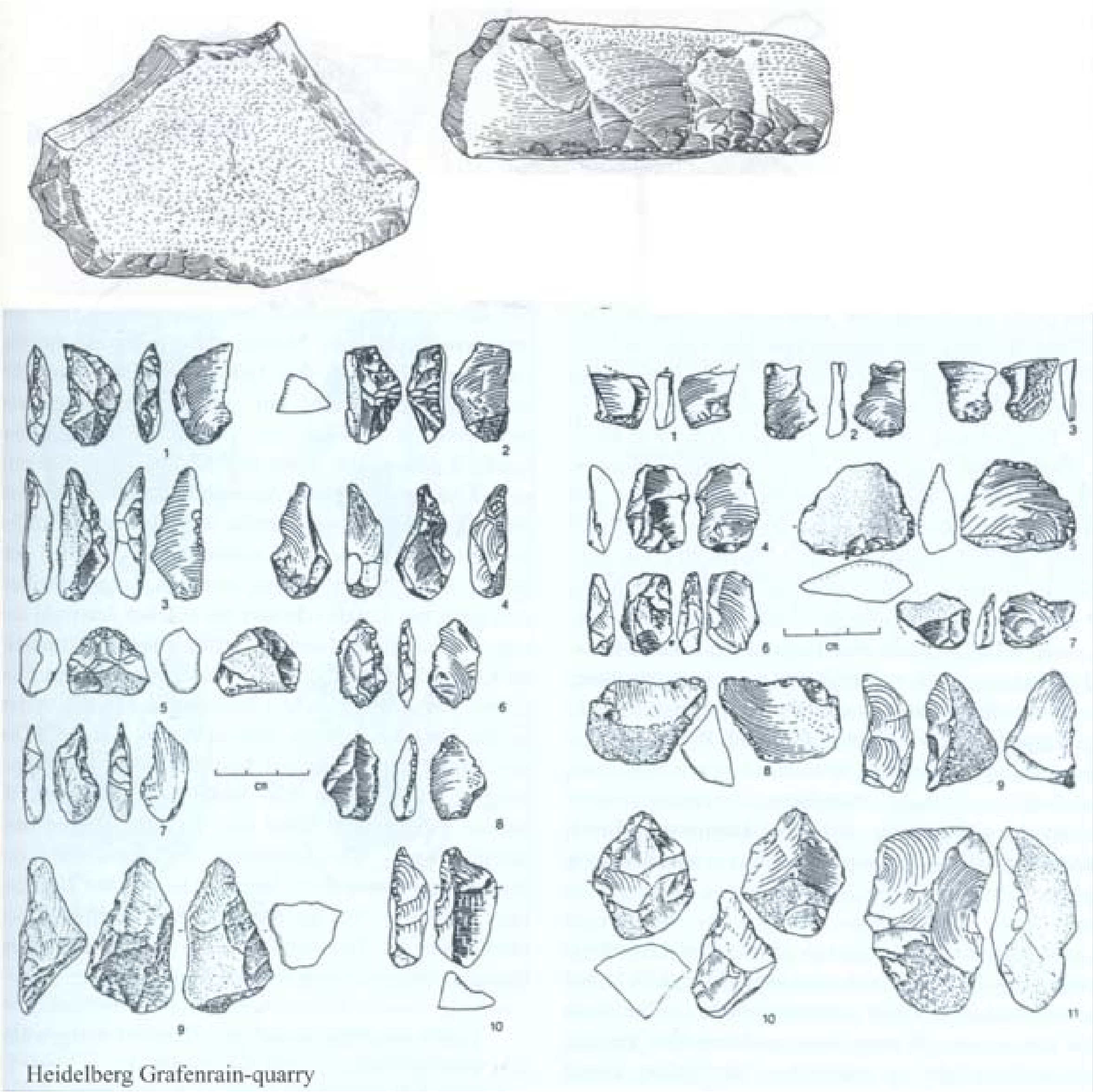
distance between anvil and hammer contact-points is great. This limits the striking force because of the risk of a straight fracture at the hammer contact-point. In the straight bipolar technique, the idiomorphic or neutral cones from the hammer and anvil overlapped eachother, but in this acute bipolar flaking the cones from both contact points do not meet. This further limits the forces involved in the fracture. This method is called the “contre-coupe” technique, it was the standard in making end-scrapers on blades in the upper palaeolithic Hamburg tradition. These contre-coupe scrapers had working edges down to 40 degrees. The great distance between hammer and anvil means the fracture shape is based on the idiomorphic or neutral core from the anvil contact-point so strictly speaking this is unipolar flaking although not freehand. In this respect this “contre-coupe” technique is related to the “block-on-block” technique, both cause fractures based on the idiomorphic cone shape. The “block-on-block” method however is a very uncontrolled proces without the use of a hammer and “contre-coupe” combines hammer and anvil in a precision technique. Other bipolar precision techniques often seen in upper palaeolithic and mesolithic context are burin production (Bertouille pays much attention to this) and bipolar blunting in the production of backed blades. It speaks for itself that upper-palaeolithic Europeans or MSA-to-LSA-transitional Africans (F. Diez-Martín) used these bipolar techniques in freehand-concept traditions.

The most special bipolar technique is the deep hollow fracture in a thick stone as we see in figure 5G. This feature is often called a Clacton-notch. I often call this a deep notch, to distinguish this from the shallow notches in thin flakes we see in the denticulated-Mousterian, contrary to such shallow notches the deep notch cannot be made in freehand technique. The Clacton-notch or deep notch is made in oblique bipolar technique by placing one contact-point a small distance from the edge and another contact point at a greater distance from the edge. Just like we have seen in pebble-decapitation (5B), the reduction face of the core now shows a convex fracture from contact-point to contact-point. And in the perpendicular direction (from left to right) this same fracture shows a deep concave surface. In all cases of oblique bipolar flaking the hammer gives the core a tendancy to turn away. This rotating momentum has to be counteracted by the hand that is holding the core on the anvil. If you remove the counteracting hand, it becomes impossible to make a deep notch because the core wil simply turn away. And if you were to substitute the counteracting hand by a second anvil, it than becomes equally impossible to make a deep notch because this places the greatest strain directly between the hammer and both anvil contacts. This will only lead to a straight fracture. Once you understand that it is close to impossible for nature to reproduce deep notches, you will consider it highly remarkable that freehand flakes (although these can be easily reproduced by nature in rockfalls) are called “diagnostic” and readily accepted as artificial. And that deep notches (and other bipolar fracture types) are called “non-diagnostic” and are therefor rejected by many scholars. It is clearly necessary that students get a better understanding of the fracture characteristics, the next chapter can be helpful at this.

CHAPTER 3: FRACTURE CHARACTERISTICS

DIAGNOSTIC FEATURES OF CONCHOIDAL FRACTURES

Schick and Toth (Making silent stones speak) claim that “stone flaked by humans normally exhibits a breakage pattern that geologists call conchoidal fracture”. Most archaeology students learn the doctrine that this conchoidal fracture pattern distinguishes artifacts from geofacts. But we have seen in chapter 1 that the conchoidal fracture is based upon the idiomorphic or neutral cone shape. And we have seen in chapter 2 that bipolar fractures are not based on the idiomorphic or neutral cone. That makes it a simple and undeniable fact that bipolar fractures are not conchoidal fractures. Fortunately the oblique (or non-axial) bipolar percussion products often resemble conchoidal fractures and therefor they are often recognised as artifacts, certainly if there is a good archaeological context like in Vértesszölös or Tautavel. But unfortunately many bipolar artifacts have been rejected in the past for not fitting the doctrine of having the correct diagnostic features. Certainly some of the Rust Heidelberg finds and Reid Moir Cromer finds have to be reconsidered as



FRACTURE CHARACTERISTICS DIAGNOSTIC FEATURES OF CONCHOIDAL FRACTURES
Figure 11: The object above was reported by Alfred Rust in 1956 (Heidelberger-Kultur). The Heidelberger-Kultur was later considered to be geofact because of the steep flaking angles. The objects below look more like "normal" flakes and handaxes and presently accepted as artifacts. Most probably however, both are selections from the same complex. Rust concentrated on large objects, from which we now understand that the steep angles indicate bipolar techniques. And the same bipolar techniques are indicated by the missing striking platforms, flat bulbs, Tayac-like objects and occasional steep angles in the collection from the Reiss-Museum below.

being artifacts, produced with bipolar techniques. To get a better understanding of cochoidal and non-conchoidal fractures we must take a closer look at the fracture characteristics.

RIM OR COLLAR
During the strike, the hammer core and anvil show deformation. As a result the contact-points are turned into round or oval contact-surfaces. In these contact surfaces there is compressive strain, around the contact surface pulling strain. So the actual rupture will be initiated in the "neutral" (compare this to the neutral cone rupture) zone around the compressed area. In cases where the rupture is initiated but not propagated, we can find a round or oval fracture line on the core surface. This is seen when a strike is too weak or misdirected, but it can sometimes also be found in oblique bipolar percussion in the contact point opposit to where the rupture was propagated. László Vértes noted that "Small circular traces can sometimes be observed on the base of some pebble choppingtools and broken pebbles".

Soft hammers show more deformation and therefor have a larger contact-surface. There is a less acute change from compression to pulling forces, so a less obvious "neutral" zone. Soft hammers therefor rarely produce rims. An explicit lip does however occur when the length of the contact-surface is more than 2.19 times the width (Bertouille).

SHATTERING
Shattering or crushing of the contact-surface is extremely rare in freehand flaking. Therefor many scholars consider shattering of contact-surfaces to be the result of geological forces. In the straight bipolar technique however, the forces are much greater than in freehand flaking and as a result shattering of the contact surfaces is common. In notching (figure 5G) there is less shattering as the notch is less deep and in normal oblique flaking (figure 5C) and oblique retouching (figure 5D an 5E) shattering of the contact-surfaces is near to absent. Artficial shattering is not only seen on contact-surfaces in straight bipolar technique, it is also found on for instance backed blades as

DEPTH OF NEGATIVES Figure 12: deep and steep flake scars on a bipolar scraper.

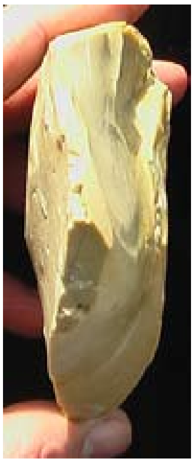
Figure 13: oblique bipolar flake, dorsal surface (compare 14-15-16). Note that oblique bipolar flakes and flake scars show great resemblance to freehand flakes. The dorsal scars and the ventral scar show the same direction (parallel flaking).

Figure 14: oblique bipolar flake, ventral surface (compare 13-15-16). Note the flattened cone and large bulbar scar as characteristic of bipolar reduction.

a means to blunt sharp ridges. And shattering is used to remove superfluous material (piquetter or pecking). On anvils shattering can be either use-wear or intentional to prevent skidding.

STRIKING PLATFORM
As we have seen the fracture is initiated at the rim of the contact-surface and from there the rupture is propagated towards the reduction face of the core. This means that the surface where the hammer struck is knocked off with the flake; this is called the striking platform. It is impossible to make freehand flakes by a hard hammer without a striking platform, in soft hammer blades the platform can be absent. In the straight bipolar technique striking

Figure 15: oblique bipolar flake, striking plane (compare 13-14-16). Note that there is no shattering of the striking plane in oblique bipolar flakes. Striking planes can be large (as in this case. A previous scar was used as striking plane, this is common in Clacton-flaking), facetted (but not formal Levallois) or absent.



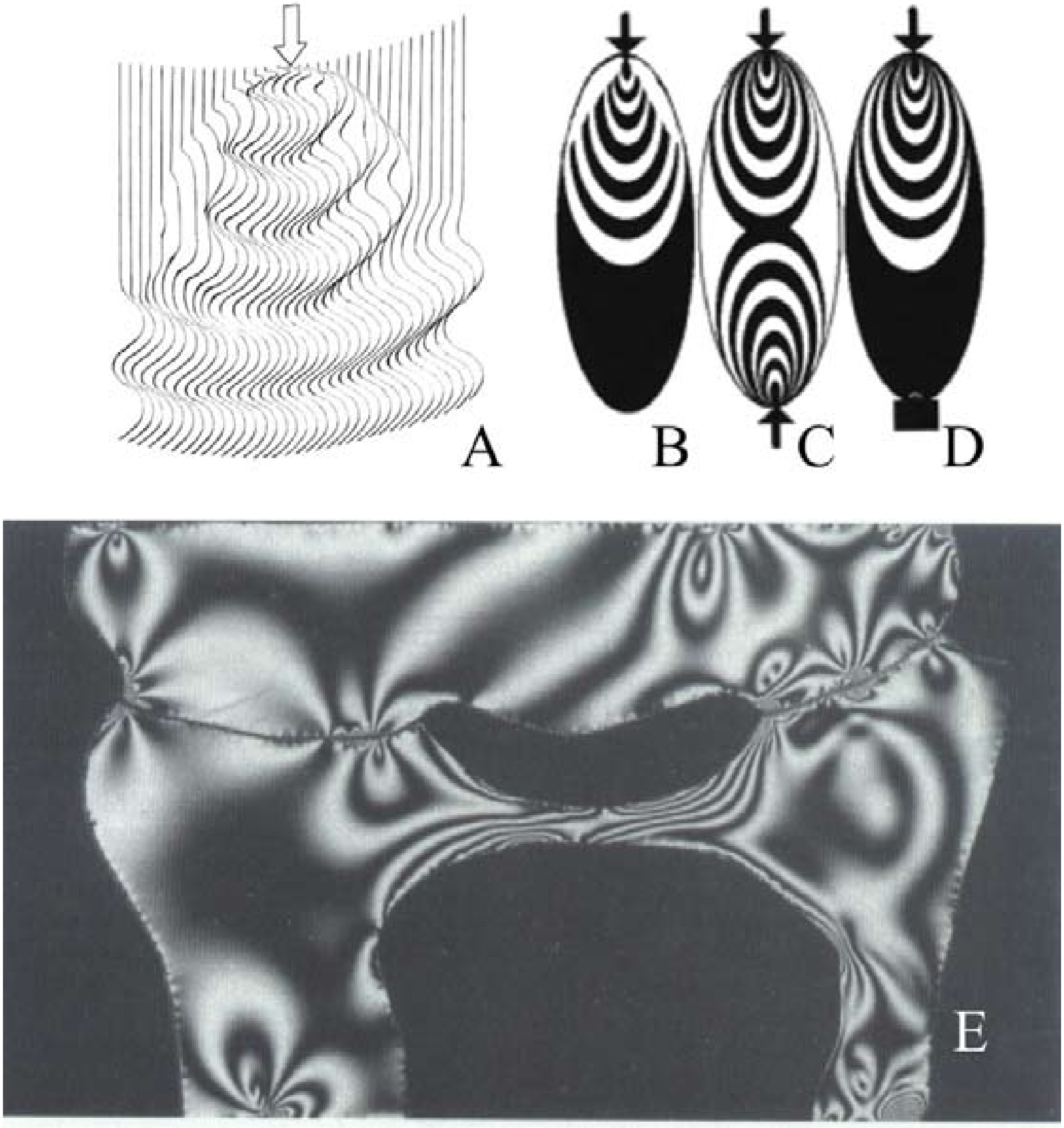
CURVATURE Figure 16: oblique bipolar flake, side view (compare 13-14-15). Note the remarkable curvature of the left dorsal flake scar. Starting from my index finger at the striking plane, this dorsal scar begins looking like a freehand conchoidal flake. But you would expect the flake scar to end at 3/5th from the top, because there the parabolic curve runs out of the core. Instead we see the scar deflecting from the parabolic curve towards the ventral surface. This curve can only be the result of strain from the anvil contact point, hence it is never seen in freehand technique. Also note the abrupt edge on the ventral surface between the large bulbar scar and the conchoidal curve.

platforms are most often absent. In oblique bipolar per cussion we often do see striking platforms that are very similar to freehand striking platforms.

STRIKING ANGLE
In freehand flaking the angle between the striking platform and the reduction face cannot be obtuse. The reason for this becomes clear, if we take another look at figure 4. The inner side of the idiomorphic or neutral cone must be directed almost parallel to the reduction face. This means that the axis of the cone must point 50 to 60 degrees to the outside. Now suppose you want to flake a core with an obtuse 110 degree angle, the axis of the cone must point forward 160 to 170 degrees from the striking platform, so the hammer must strike the platform at an angle of 10 to 20 degrees. Striking at this angle cannot produce an effective compression of the core, the hammer will bounce off. In bipolar flaking the angle of the fracture is not determined by the neutral cone, instead the angle is determined by the choise of hammer and anvil contact-points. For practical reasons most oblique percussion flakes resemble the freehand flakes, but making obtuse and acute angles is certainly possible using bipolar techniques.

DEPTH OF NEGATIVES
If flakes are removed from a core in freehand technique, the negatives are slightly concave. But in oblique bipolar flaking the negatives tend to be more concave. In Vértesszölös, László Vértes noted as he put it that “The flake scars are deep and concave”. As mentioned above, the deepest and concavest flake scar is what we call a deep notch or Clacton-notch and these deep notches can only be made in bipolar technique (figure 5G).

CURVATURE
As Bertouille noted, freehand flakes tend to follow a parabolic curve. The best blades can therefor be struck



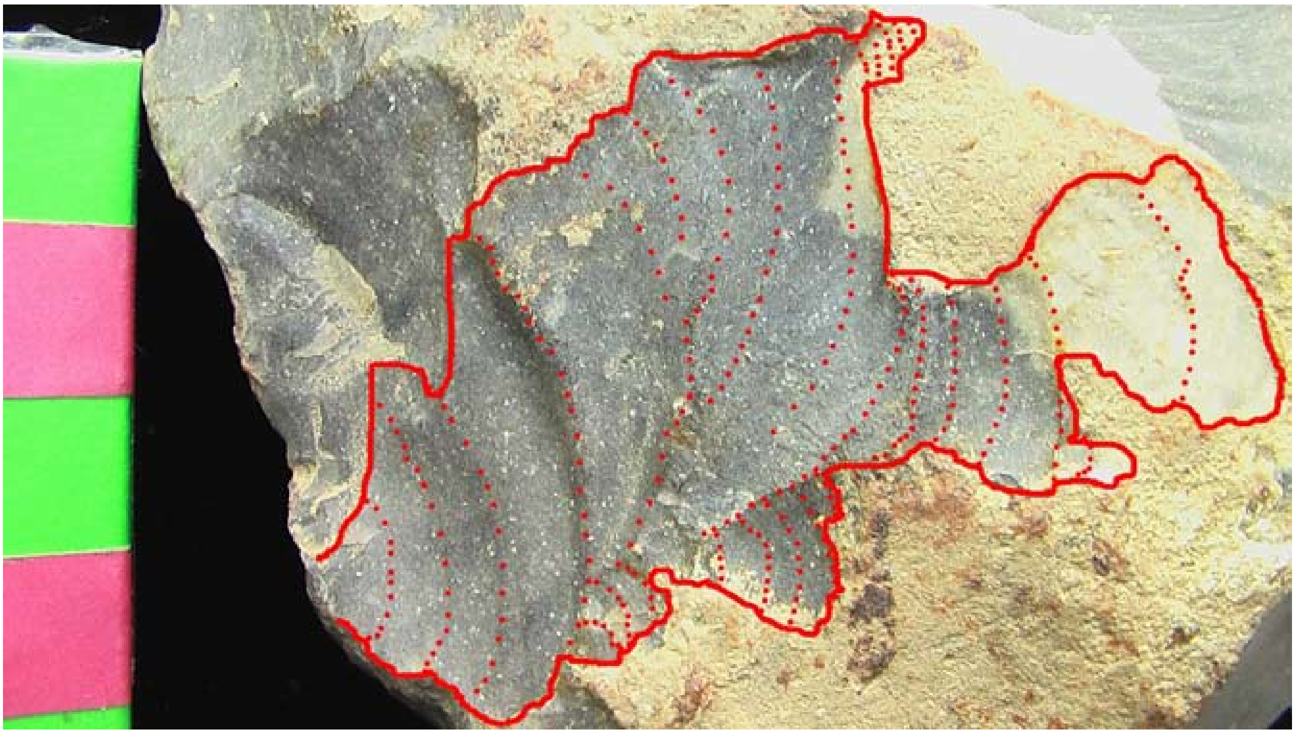
RIPPLE MARKS Figure 17: A in freehand flakes ripple marks are absent outside the cone. B ripple marks are distributed like a peacock-eye pressure pattern C bipolar ripple patterns can only occur in straight bipolar reduction D a larger contact-surface prevents appearance of the peacock-eye pattern E polariscopic picture of a complex pressure system.

from a core that has a parabolic reduction face (i.e. a “livre de beurre” core). As we have shown in figure 4, the curvature of the freehand conchoidal fracture is influenced by the shape of the reduction face but it nevertheless remains an almost parabolic curve. In other words, if you follow the fracture from the bulb to the distal end, the curve will only become flatter. It will not bend backwards towards the core. In bipolar percussion however, the supposed distal end of a blade or flake can get a stronger backward curvature. The obvious reason for these surprising curves is that the bipolar fracture runs from contact-point to contact-point. So the supposed distal end is actually very near to a contact-point and the rupture bends under the strain from that nearby contact-point. Such strangely curved flakes and blades are not common but some are shown on my DVD “the bipolar toolkit concept”.

BULB

The bulb (or semicone) of percussion is a swelling that sits on top of the parabolic fracture line just below the striking platform. This swelling tends to be larger if the flake is thicker. The reason for this swelling is the Boussinesq ball or sphere. To understand this phenomenon it is best to think of the core as if it is very large (semi-infinite). In such a large core an actual rupture is impossible (either according to the neutral cone or from contact-point to contact-point). Nevertheless the strike builds up strain and the only form that this strain can create is a growing ball or sphere. When we are flaking a core, the further we place the hammer-strike from the edge, the more it acts as a semi-infinite body. In other words, the thicker the flake is the longer the strain will build up as a Boussinesq ball. This explains why thick flakes have large percussion bulbs.

The bulb is also influenced by the materials. If a softer hammer is used, the hammer contact-surface is larger. The Boussinesq ball is now no longer concentrated under one point, it is spread under each point of the large contact-surface. This blurs the edge of the ball and if we add-up all individual points the bulb is flattened. The material of the core also influences the bulb shape. As I mentioned under placing and directing the strike, flint is not completely isotropic. There are small cavities giving the core a spongy structure. The same goes for instance for sandy-quartzites. As the fracture passes through these cavities this also flattens the bulb.



RIPPLE MARKS Figure 18: detail of freehand flaking on a Halbkeil. The ripples of one flake scar are accentuated by dotted lines. These ripple marks are neither circular nor concentric, instead they show a complex pressure distribution.

RIPPLE MARKS
There are wavelike undulations on the surface that resemble the circular ripples on water when a pebble is dropped in a pool. Therefor it is often thought that these ripples represent vibrations of the core during the progression of the fracture. But on closer look these ripple marks are not concentric, they look more like a series of (ever larger) rings hanging on the same nail; not the centre of all rings but the side of all rings meet in the striking-point. Such a pattern is never seen when a pebble is dropped in water, it is not an undulation pattern. These patterns are called “oeil de paon” or peacock-eye patterns. These peacock-eye patterns become visible when polarised monochomatic light goes through models that are put under pressure, peacock-eye patterns are strain patterns. The ripple marks that we see close to the distal rim of the flake seem to have very little relation to the striking-point, instead they are running parallel to the distal rim of the flake. This is yet another clear indication that the ripple marks belong to a pressure-strain system. We must conclude that the ripples are due to strain or deformation of the stone, but this doesn’t mean that the stone is actually bending and rippling.

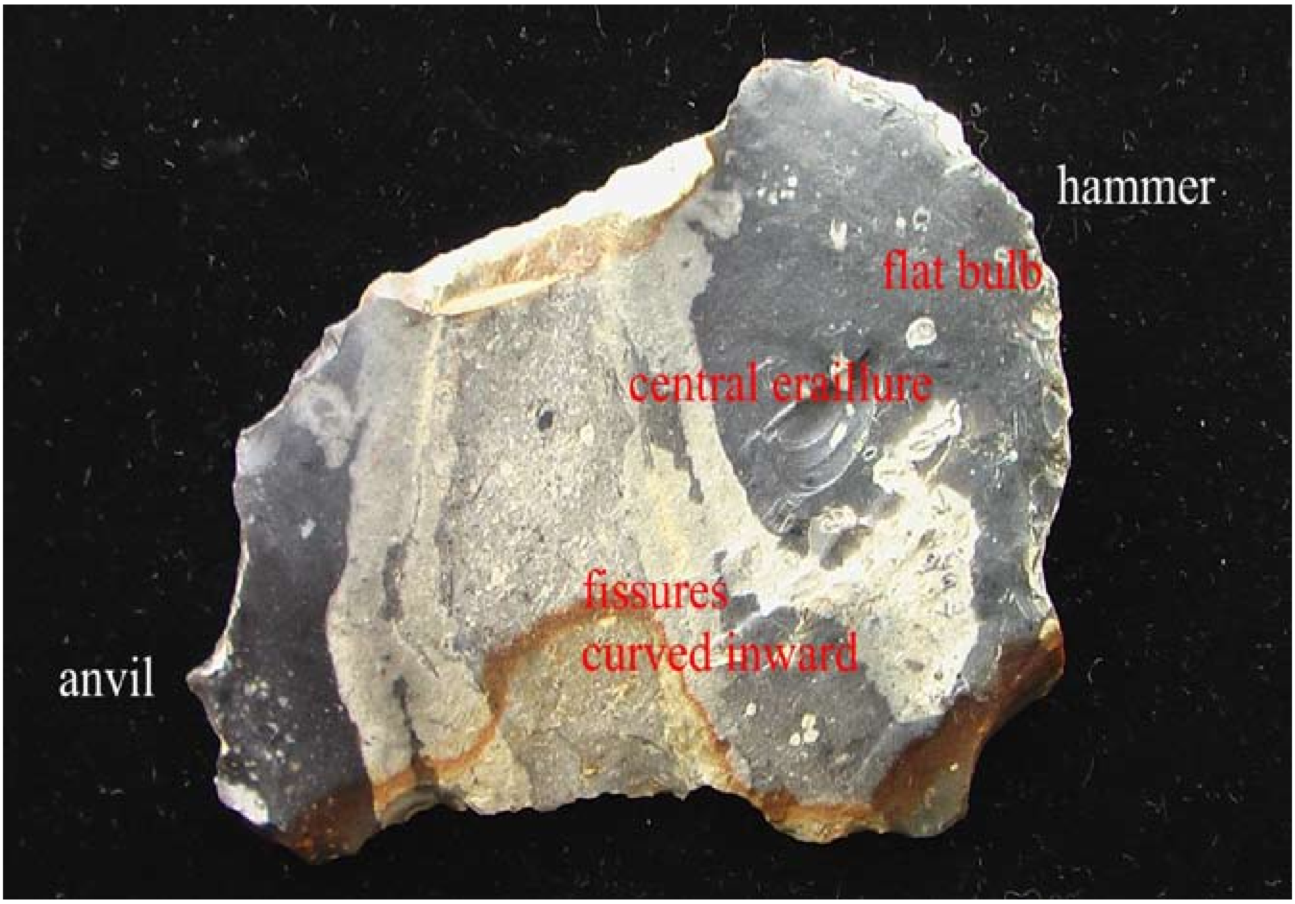
Perhaps this becomes somewhat easier to understand, if we compare the stone to a book. This book has 2000 pages that are all glued together to become one solid isotropic mass. We put the book on an anvil with the contact-point exactly on page 1000 and the hammer strikes also exactly on page 1000. This places the largest strain on page 1000 so we might expect the book to break open at a readable page 1000. But as the pressure is building up, the lines on page 1000 become compressed more than the lines on the adjacent pages. As a result the compressive strain starts to look for an easy way out. The strain in the first line pushes a little to the front so now the greatest strain is on page 995. The strain in the third line pushes a little to the back so the greatest strain in the third line is on page 1005. And the greatest strain in line two remains stuck in the middle on page 1000. When we look at the end result after the fracture, we see ripples that are the result of strain or deformation. But of course the book has a rigid structure so we are not looking at a rippled and readable page 1000. What we are looking at is the first line of page 995, the second of 1000, the third of 1005, the fourth of 1000, the fifth line of page 995 and so on. Now we only have to substitute the book by a stone and the simple lines by the peacock-eye pattern. Than we understand how the strain in the form of a microscopic deformation of structural units, can lead to large and clearly visible ripples.

CONE
Sometimes a clear-cut cone is visible just below the striking platform. As we learned in figure 1 the fracture surface inside the cone was formed under compressive-strain and outside the cone under pulling-strain. Therefor the inner part of the cone has ripple marks, running from the bulb (peacock-eye strain-pattern) to the distal end (parallel strain-pattern). And in freehand flakes the part outside the cone has no ripple marks (pulling force smooth surface). So the cone is accentuated by this pattern.

A cone can also be seen in oblique bipolar fractures. But as the surface outside the cone experiences some compressive-strain from the opposit contact-point, the surfaces inside and outside the cone show less contrast. This lack of contrast is often called a flattened or diffuse bulb (László Vértes noted that about half the bulbs in Vértesszölös were diffuse).

When the hammer-strike is too weak, it will produce a dead-end cone. Some flaked surfaces show a dead-end cone next to the normal cone. Such double coned surfaces seem to be more frequent in large Clactonian flakes.

ÉRAILLURE AND FISSURES
The fissures are very fine lines, radiating from the point of percussion. And the spot on the bulb where a paper-thin flake is missing, is called the bulbar scar or éraillure. Both types of disturbance of the rupture are caused by the same physical phenomenon. This phenomenon is the progression of a linear structure (the rupture front) through strained material.



ÉRAILLURE AND FISSURES Figure 19: a nearly straight bipolar flake, showing a central éraillure and fissures that show the propagation of the rupture bends more towards the anvil contact here than towards the outside of the flake.

This might be difficult to understand, you should make a three dimensional image of the strained core in your mind. You would expect the rupture front to move at a fixed speed. But if the structural units are compressed, the rupture will reach the other side sooner so the propagation of the rupture is faster! So in strained stone, the rupture front can move at a different speeds parallel tot the reduction face or perpendicular to the reduction face. This means that if we start with a linear rupture, it very soon gets a third dimension, the line changes into a spiral! When we understand that a line changes into a spiral as it is propagated in strained material, the rest is simple. The rupture has to follow the plain of the greatest strain, in freehand flaking the plain of the greatest strain is shaped by the neutral cone and in bipolar fractures it is imposed by the contact-points. The rupture front has to follow that imposed plain. But on the other hand, as the rupture front progresses it wants to spiral out of the imposed plain. This desired spiral conflicts with the imposed line and as you may expect in any conflict, occasionally the situation goes out of hand. The spiraling rupture derails from the imposed plain causing the éraillure and fissures.

Of course the conflict is at its largest where the strain is at its largest. In freehand flaking this is just below the striking-point on top of the bulb. So here the fracture spirals totally out of the imposed plain, and this produces the bulbar scar or éraillure. In bipolar fractures the strain pattern can be very different resulting in a different éraillure pattern. For instance if the strain is very large, this can sometimes produce a very large bulbar scar. And if the largest strain is halfway between the two contact-points, the scar or éraillure will be in the centre of the fracture. I explained in figure 4 that the deformation is easier near to the outside of the core, this explains why the fissures are often seen nearer to the edges of the flake. And I explained that the cone can be accentuated because of the inversion of the strain, this explains why the fissures can also be strong near the sides of the cone.

GENERAL OBSERVATIONS AND CONCLUSIONS

The intentions of freehand techniques and bipolar techniques are very different from eachother. Figure 2 has learned us that in freehand techniques, the tool-maker always wants to peel-off flakes from the core. Figure 5 showed us that the toolmaker using the bipolar concept is not trying to peel-off but to break open. This is most obvious in the straight bipolar technique, but oblique bipolar techniques are also more invasive than freehand flaking. This can be concluded from the deep flake scars, denticulates and notches.

There is a very close link between the technique and the shape of the implement. If you resharpen a large flake by peeling-off smaller flakes in freehand technique, this will create a large cutting tool and eventually a handax. The bifacial handax is no more and no less than the logical consequence of freehand flaking and as a result it became widespread in the palaeolithic. The bipolar breaking-open concept on the other hand does not invite to make handaxes, this concept leads to notches, Tayac-points, denticulates, polyhedrons and nosed artifacts (Nasenschaber). Since the technical concept determines the toolshapes, the typological description of the toolkit is really the first essential step in determining the techniques that were used. Bifacial handax groups were based upon the freehand flaking concept and pebbletool, Clactonian and Tayacian groups were based upon the bipolar concept. You can get more aquainted with both toolkits by watching my film “the bipolar toolkit concept”. The next step in determining the techniques is to find confirmation in the signals of the fractures such as flaking angles, cones, bulbs.

The bipolar toolkit concept gives us a better understanding of technological developments in the palaeolithic period. In concept the early Oldowan toolkit was definitely bipolar, and with the first “out of Africa” migration wave around 1.8 million years ago this succesfull concept became spread over Eurasia. In spite of the definit bipolar toolkit however, in Africa some opportunistic freehand flaking occurred from the earliest times on. Where large isotropic raw material was available, freehand flaking proved to be a succesfull way of resharpening large flakes. This lead to traditions that had a basic bipolar Oldowan toolkit in combination with freehand large cutting tools that were developing into handaxes, around 1.5 million years ago. From these transitional industries (i.e. TK, BK) the completely freehand Acheulean was developed. At just over a million years ago the great succes of the early-Acheulean lead to the middle-Acheulean, characterised by freehand prepared core technique (i.e. Canteen Koppie). The Ubeidiya industry at the doorstep of Eurasia also contains handaxes, but in spite of the succes in Africa handaxes did not yet venture into Eurasia. When we understand the freehand and bipolar toolkit concepts, the reason for this is obvious. The freehand-handax concept was ideal in open landscapes for specialised hunter-scavenger groups and was less equipped for the life in warm forests and river deltas where large isotropic raw material was unavailable. In such areas it was the bipolar toolkit concept that flourished. The open plains from the European landscape were for the larger part steppes with cold winters. Therefor hominids could only survive on the steppe after the invention of clothes (according to DNA studies in lice this was around 600.000 years ago) and therefor the Acheulean freehand-handax culture only became widespread in Europe after the invention of clothing. Even at the time that the Acheulean was widespread in Europe, the bipolar toolkit concept remained the best survival strategy in warm forests and river deltas where large isotropic raw material was unavailable. As a result the freehand cultures and bipolar cultures coexisted in Europe during the larger part of the middle pleistocene. Our understanding of the bipolar toolkit concept, has thereby explained that seemingly “primitive” traditions like the Clactonian or Bilzingsleben flourished when handaxes and prepared cores had long been developed in Europe. Although it is very admirable that Mania (D.Mania, T.Weber: Bilzingsleben III. Berlin 1986) measured and counted striking platforms, flaked surfaces, fracture angles and so on, it is the understanding of bipolar techniques that explains the different cultural signals. When Mania for instance speaks of an “old-palaeolithic level of core-exploitation”, this level should not be seen as a measurement for skill or even intelligence, it is only related to choises in lithic technology.

Much remains to be investigated about the bipolar toolkit concept, about its relations to climate, raw material, hominid types, about the influences of climatic shift on population size and inherently on collective memory processes as one important reason for the cultural differences between the African and Eurasian palaeolithic. The bipolar toolkit concept is at this moment the largest unexplored field in archaeology, a world of discoveries is awaiting us.