Flint Knapping: Basic Concepts

Compiled/Edited by Michael Lynn

Photo of Tim Dillard teaching me at the
Center for American Archaeology in Kampsville, IL

Dedicated to all those who have taught someone else about the art of flint knapping, especially to my primary teachers – Bruce Boda, Tim Dillard, Mike McGrath and Steve Nissly. This is my attempt to pay forward.

Flint Knapping: Basic Concepts

Flintknapping Terminology

by Mark Bracken

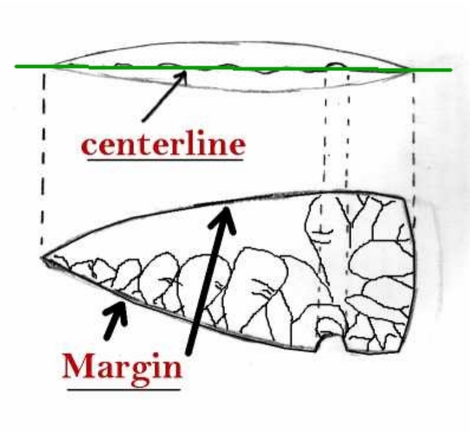
Here are some helpful descriptive terms commonly used in knapping...

• Abrading... The process of polishing the edge of a preform's platform to strengthen it in preparation for flake removal by percussion or pressure flaking.

• Biface... A spall or piece of flint that has been flaked on both sides.

• Bulb... Often called "The bulb of percussion" it is the area very close to the edge or margin of the biface where the flake originates due to pressure or percussion work. It can sometimes be deep and cause significant concavities along the edge. The bulb should be kept at a minimum. See drawing

• Center Line...This term is used to describe the imaginary centerline of a preform as viewed from the blade edge. See drawing



• Cobble...Some flints occur in cobble form. These are irregular shaped but smooth, and are formed in various sizes averaging from one to 5 pounds and are generally covered with a cortex.

• Concave... A"cupped" area on the face of a preform or nodule. This should be avoided until the material around it has been removed thus raising this "negative" area to match the contour of the rest of the Blade or core.

• Convex... The opposite of concaved. It is a rounded raised area. A lens shape is a good example. This is the foundation for good successful flaking!

• Core... The "mother stone" or nodule which spalls are removed from. Also a carefully prepared worked piece of flint that Sharp useable blades are removed from.

• Cortex... The outer "skin" of a flint nodule or spall. Usually a chalky white or brown material ranging from 1" to 1/4" thick.

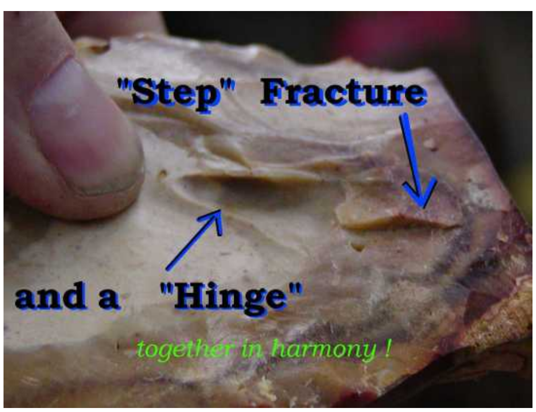
• Flake... A thin, sometimes broad and sharp piece of stone chipped from a larger biface or preform.

• Flake Scar... This is the "scar" left behind where a flake has been removed.

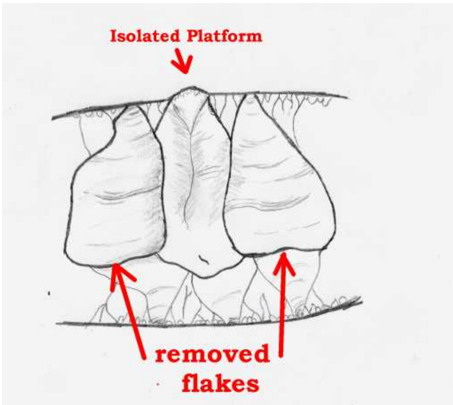
• Flute Flake... A special flake removed from the base of a blade or preform that travels up the face towards the tip. The purpose of this flake was to create a concaved channel to aid in the special hafting technique of Paleo era points.

• Heat Treating... Flint was often heat treated by North American peoples. Things are no different today! The flint is very slowly heated and cooled to temperatures ranging from 350-700 F, depending on the material quality and type. Not all flints benefit from heat treating. Heat treating gives the flint a glass like attribute making it easier to chip.

• Hinge Fracture... This is an undesirable flake that falls short of it's mark by " rolling" out. See image.



• Isolated Platform... This is a platform that has been "isolated" from the material around it. This is done by carefully chipping the stone away from either side of it. This leaves the platform sticking out a bit. The energy is transfered much farther "down range" using isolations.



• Knapping... The skillful act of chipping flint or making gun flints.

• Margin... The edge or circumference of the biface or preform.

• Nodule... A large to very large smooth or irregular piece of flint.

• Overshot Flake... The affect of a flake that travels from one margin to the other and "clipping" the opposite edge.

• Platform... A platform has 3 main components, this is discussed in "platforms". A carefully prepared area on the edge of a preform to be struck to create the desired flake. Or A naturally occurring area on a rough spall or nodule that would produce a desired flake or spall. Platforms are the key to good knapping.

• Platform Bevel... This is the part of the platform that is actually struck.

• Platform Support... This is the underside of the "bevel". It gives support to the platform at the time of strike.

• Platform deltas... These are the results of flake removal. See drawing

• Preform... A bifaced blade in various stages of reduction.

- **Pressure Flaking**... The act of removing flakes by pressure using an "Ishi Stick" or flaker.

- **Percussion Flaking**... Removing flakes by directly striking the stone with a billet.

- **Raking and Shearing**... Raking is the action of carefully dragging a course abrader or other device to remove "micro" flakes from the edge of a biface or preform to change it's shape or give support to an edge before actual abrading is done prior to percussion or pressure work.

- **Spalling**... The act of breaking up a nodule or cobble into workable and desirable sized pieces.

- **Spalls**... The finished untrimmed large flake removed from a larger "mother" stone.

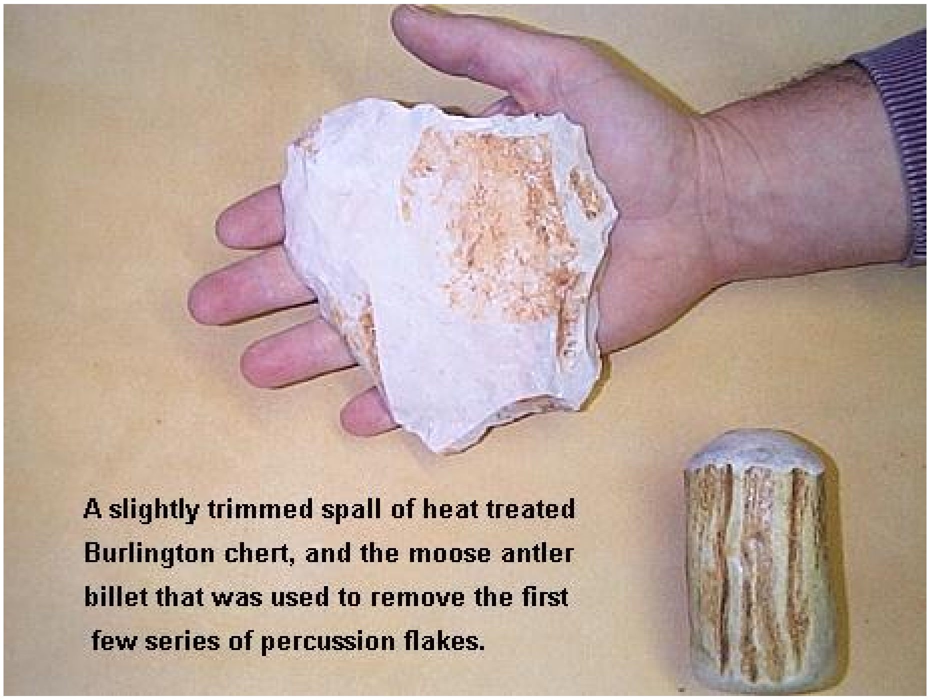
- **Stack**... Another BAD thing. A series flakes that fall short of a single specific objective. Resulting in multiple failed attempts to remove a specific problem area. Read"Platforms" for preventative measures.

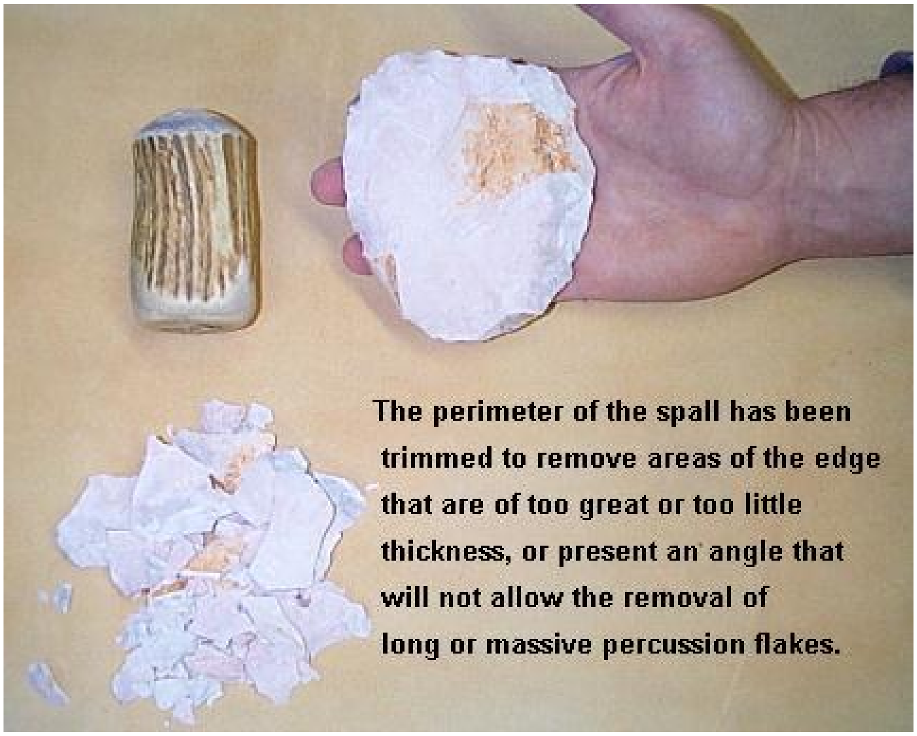
- **Step Fracture**... A single flake falling short of it's mark by creating a "step" on the surface of the Blade. The thinner you get the more this demon haunts you.

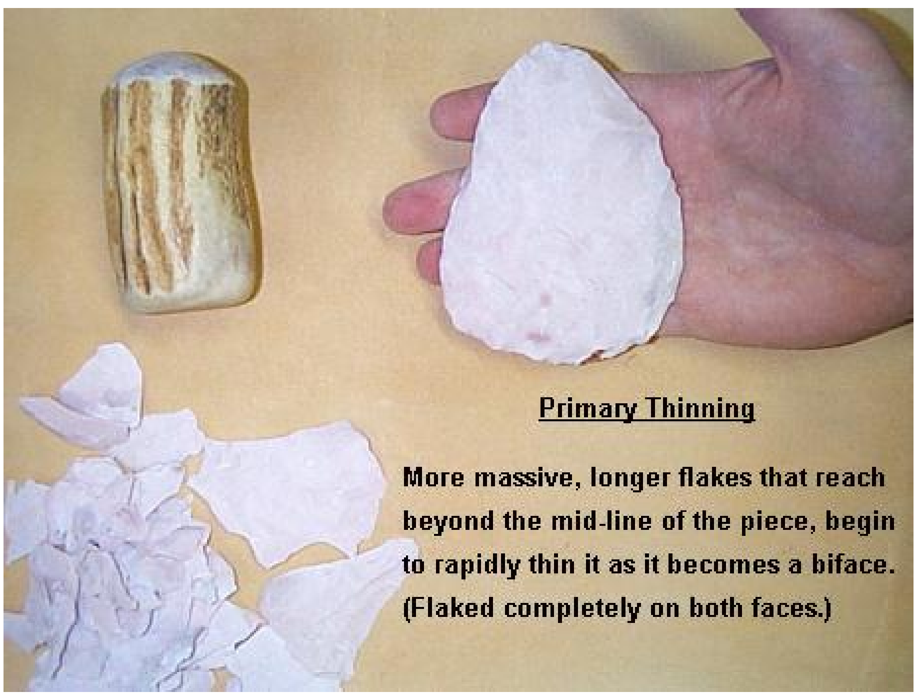
From http://www.flintknappingtools.com/terms.html , March 31, 2010, copied with permission

Reduction Sequence

by Dan Long




The perimeter of the spall has been
trimmed to remove areas of the edge
that are of too great or too little
thickness, or present an angle that
will not allow the removal of
long or massive percussion flakes.

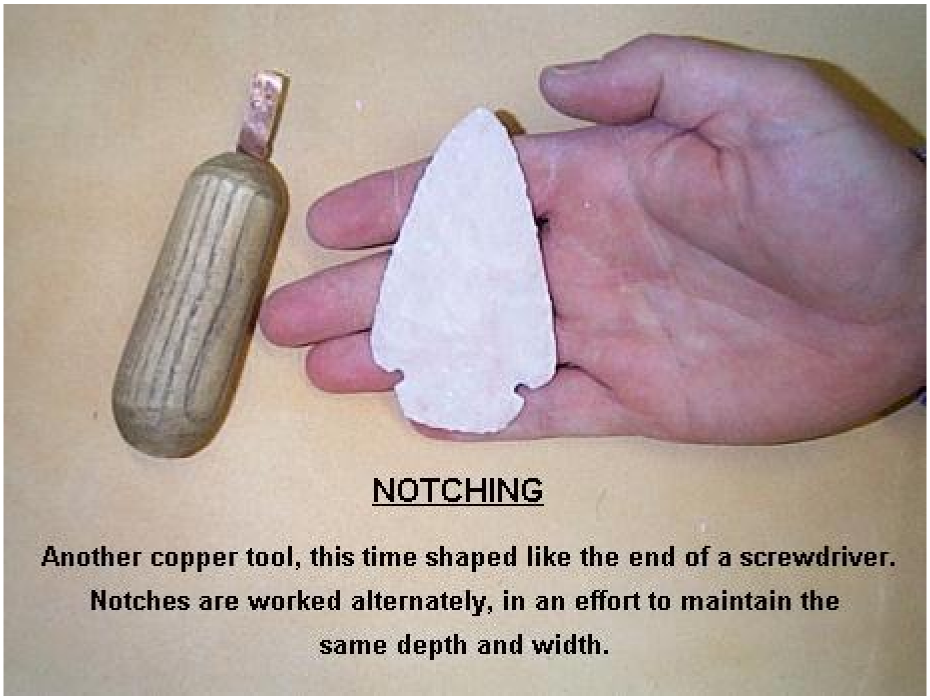

Primary Thinning
More massive, longer flakes that reach
beyond the mid-line of the piece, begin
to rapidly thin it as it becomes a biface.
(Flaked completely on both faces.)


As thinning continues (with a smaller billet), the flakes are less massive but still long, reaching more than halfway across the face.


Moving again to a smaller billet as the biface begins to take shape.
The mass of the billet should be in proportion with the size of the biface and the desired flakes.


The smallest billet used in this reduction for the final percussion flakes.
The corners have been removed from the base of the preform in preparation for corner notching.


PRESSURE FLAKING
A copper tipped tool is used to push small flakes off of the edge for final shaping. The edge is also thinned, sharpened and straightened by this action.


NOTCHING
Another copper tool, this time shaped like the end of a screwdriver.
Notches are worked alternately, in an effort to maintain the
same depth and width.

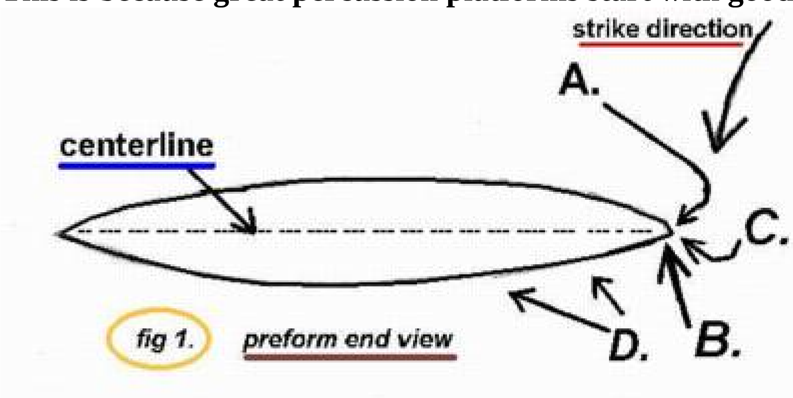

With notching, final base and edge
retouch complete, the base and insides
of the notches are ground smooth in
preparation for hafting onto a handle
for use as a knife.

From http://knapper_dan.tripod.com/, March 31, 2010, copied with permission

Anatomy of a Platform

by Mark Bracken

Careful and properly built striking platforms are one major key to predictable flake removal. Please note that one must have an understand knapping "terminology" to benefit from this article. Platforms have four basic components. All four components must have the proper characteristics for a flake to be removed predictably, and if it does not, the struck flake (if any) WILL become undesirable. Lets look at the platform's components and why each part is so essential. You must understand that these four components almost always have to be created from scratch. Rarely are they just sitting there waiting for your eager billet! These are also listed in the order they should be made. The descriptions here are intended for bi-facial preform stages but can be applied to spalls. Note that one must be quite proficient with a pressure flaker before you master percussion flaking. This is because great percussion platforms start with good pressure flaking.



Now that we have divided the platform into four parts, lets give them all a letter code: "A", "B", "C" and "D", as shown in fig. 1. I will discuss the following topics relating to each platform component.

1. It's purpose and/or function
2. "How to make them"
3. The attributes it should have
4. Trouble shooting... cause and effect of poorly made and or Improperly prepared platforms

Part A

The first we will look at is "A". This is the part commonly referred to as the "bevel". The purpose of the "bevel" is that it serves as the surface that is actually struck to produce the flake. How do we go about making the bevel? The most accurate way is to use a SHARP pressure flaker. You can use a billet to produce this on an early stage perform or spall. It is highly recommended that you use a pressure flaker to make this part. What attributes should part "A" have? This part should have a bevel some where near 45 degrees. This angle can be changed by making another "pass" or modifying angle of pressure. The bevel should be smooth. What I mean by this is that it should not contain irregular bumps, humps and micro ridges. It should be just as if you used a router on a piece of wood.

Part B

Part "B" gives support to the strike. It is actually made from part "A". There are many ways to make this. The basic idea is that you're actually removing extremely tiny chips off the bottom or underside of the "bevel". (This is the same side the thinning flake will be removed from.) Remember, your not really abrading the edge so much as shaping it. Here's a couple ways of doing this. The first way is to use a course abrader. Just rake the edge downward gently and repeating this process just long enough to feel less resistance as the abrader is raked downward. You can also rake off these "micro" flakes with the edge of your pressure flaker or use a copper bar to do the same thing. Keep in mind this is a very important step! If you rake it too hard or use or use excessive force it will be too strong and will greatly stress the stone upon striking it. Rake thick performs harder than thin ones. If "B" is not raked enough it will cause the platform to crush or cause a step fracture very close to the edge. Too much and you will break it! So don't over do it.

Part C

Moving onto part "C". This part is also made from "A". It is the polished area that your billet actually strikes. It is better described as polished but commonly referred to as abraded. Polishing sounds so much more precise and civilized. To prepare this part properly one must first have created "A" and "B" flawlessly! You simply grind up and down the platform edge. What I mean by this is your grinding from base to tip. Another description of this is if you're holding the preform flat, the grinding motion is horizontal NOT vertical. A vertical motion will destroy the platform. You want to use course abraders for preforms thicker than 5 to 1 width to thickness and a medium abrader for thinner bi-faces. Be cautious not to over grind, this will also cause splits or breakage. Keep in mind... the better you make your platforms... the less grinding they will need!

Part D

Finally part "D". This is what I like to refer to as the "road" the flake will travel down. This must be closely looked at before you decide to remove any material for the purpose of platform construction. If the surface area of part "D" is irregular, then it must be corrected before an attempt at flake removal is made. Simply put, don't waist the time and circumference of your bi-face trying to chip off an area with a stack or concavity. Just work on either side of it. Build platforms to target areas with good convexities. Stay away from concavities. You can modify the surface of your bi-face by pressure flaking if necessary. You must be careful not to cause "micro" steps with your billet or Ishi stick. It will just be more trash for your thinning flake to contend with. Just remember to take your time and analyze. Be safe and have fun!

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The Below the Center Line Concept

OK...I'll admit it. Just don't snicker and talk about it to anyone, OK? As a beginner, for the longest time, I just couldn't grasp the concept of the center line. Now I don't claim to be a genius, but still... I see myself as fairly quick on the draw. So what was the deal?

First I was confusing my working edge with the center line. Then when I realized that wasn't always so I had trouble visualizing just where it was. But finally I got it! Now it seems so painfully obvious to me I wonder why I had so much trouble with it. I don't feel too bad though, because on Craig Ratzats video "Caught Knapping" he says that this concept is a difficult one for some to grasp.

Mastering the center line concept can help you become a more successful knapper because it helps reduce breakage due to hitting too high into the mass of a preform. Later, as you gain experience, you will learn how to "cheat with the angles" so that you don't have to lose as much size due to taking off part of your edge to get below the centerline.

Well, let's explore the center line concept.

First of all understand that we're talking about the center line of the mass. Let's say you have a piece of stone worked down until it's fairly elliptical. It's a preform now. Hold the preform so that you're looking at it edge on. The drawing in Figure 1 shows this view.

Fig.1

As we look at this piece edge on, we imagine a line extending across the top surface, and also one skimming the bottom. This is depicted in figure one by the two light blue lines. Now all we do is split the distance between those two lines exactly in half and imagine a line that extends through the stone (purple dotted line in Fig.1). This is the center line of that mass.(Seems like it could be called "The Center Plane")

Here's the deal. Until you have lots of experience you must promise this to your flintknappin' self. EVERY time that you are about to strike a platform CHECK to be sure that the place where your billet will connect is BELOW THE CENTER LINE. Platforms made and struck below the center line make flakes. When you hit above the center line you fold the piece!

Fig.2

Next we can take a look at figure two. It shows a preform with an irregular edge. The center line has been drawn in as a light blue line and, as you can see, sometimes the edge is above the center line and sometimes it is below it. The two places marked with red X's are safe platforms (striking places). Just for kicks you can imagine the preform in figure two turned upside down. Now where are the safe, below the centerline strikes?

You may wonder why I didn't mark the left side as a safe hit even though there is material below the center line. That's because the angle isn't right on that end for an effective strike. It's leaning the wrong way. Platforms have to be at an angle of less than 90 degrees. You would have to chip or pressure flake at that end until the angle was not only below the center line, but also at an angle less than 90 degrees. But check this out! If you turn the preform upside down you have a platform that fits all the criteria just mentioned. On top of that, if you take a flake off there and then turn the piece back over again, you will not only have thinned one side, but with just a little retouch you will also have prepared a platform for taking a flake off the other side. Nice technique!

A  B

Fig.3

Finally, lets look at the dilemma presented here by the preform in Figure 3. It's a common scenario, but with experience it's usually pretty obvious. More often you deal with a more subtle version of this example.

We started our light blue center line at end "B" and extended it across the point to end "A". But look what happened to the line when it got to the "A" end. Suddenly it's not in the center of the mass anymore. If we were to strike a platform at this line the piece would very likely fail. The only thing to do is to move the edge down so that our platform would be below the center line of the mass at that end. The real center line of that end is indicated by the purple line. Now we can hit our platform and, providing we're holding the preform at the proper angle, a flake will be removed and things will be very happy.

So next time when you're working on a nice piece and you strike and nothing happens but a sick "clunk" noise...STOP! Where's your platform? Whew! You lucked out--it didn't break. Now move that platform down and try again! Good Luck and Happy Chipping!

From http://www.onagocag.com/center.html, April 1 2010, Copied with permission

Note: Wyatt R. Knapp is the author of "The New Atlatl and Dart Workbook" to be released Summer 2010.

Flakes from Flat Surfaces

by Jim Winn (January 27, 2003)

I did some more test flaking on obsidian slabs to observe the shape of the flakes removed. Flakes were removed with pressure using an Ishi stick with a copper tip and another with an antler tip on the 1st test. And a 2nd test was performed with percussion using both copper and antler. All of the slabs were photographed afterward showing the slabs as well as the tools used.

The following picture shows the results of the first test done with pressure flaking.

Two slabs that were pressure flaked using an antler tipped Ishi stick are shown on the left. Two more slabs that were pressure flaked using a copper tipped Ishi stick are shown on the right. The slotted rubber/leather pad shown at the bottom was used to support the slabs in the left hand and allowed the flake to travel without interference. The flakes removed with both antler and copper were all elliptical in shape and only slightly longer than their width. I was unable to significantly increase the length to width ratio using copper or antler regardless of the direction or the amount of applied force.

This next picture shows the results of the 2nd test using percussion flaking.

The two slabs on the left were percussion flaked using antler. Those on the right were percussion flaked using solid copper. In both cases all of the flakes removed were elliptical in shape and similar to those removed with pressure flaking. Some of the flakes were slightly wider than their length which was mainly a result of the edge angle (platform) being nearly 90 degrees. These flakes feathered out along the sides and terminated a little short at the distal end. The lower left flake has a platform closer to about 60 degrees and the flake was nearly round in shape.

OK, so what does all this prove? Well, it seems that the type of tool used (copper or antler) as well as the method of removal (percussion or antler) have little impact on the shape of the flake removed! There may be some minor differences that I could not detect, but they are insignificant. Of course, this only applies to a flat surface which provides ideal conditions and repeatability. Is this knowledge of value when removing flakes from an irregular surface, such as a biface? I think it is. That is just my opinion, but the whole purpose of performing a test like this is to gain insight into what can be expected under typical conditions that are not perfect (the surfaces we encounter in bi-facial reduction). I'm going to make the assumption that the shape of a flake removed from any surface has little to do with the type of tool used (copper or antler) or the method of removal (percussion or pressure). Instead, I believe that the primary determining factors in the shape of any flake removed from any surface are primarily a result of the following.

1. The shape of the surface where the flake is to be removed. The flake will follow ridges if they exist and it will fan out on flat surfaces.

2. The point at which the pressure is applied (when pressure flaking) or the point of impact (when percussion flaking). This will determine the initial thickness of the flake as it begins its travel.

3. The amount of applied force. This factor affects the mass and shape of the flake removed. More force is required to initiate fracture as the platform depth is increased (or the depth below the surface at which the pressure flaker makes contact).

4. The direction of applied force, including both the depth (or downward) direction as well as the direction across the face of the bi-face whether it be at 90 degrees or diagonally.

All of these factors directly affect the final shape of the flake detached. The type of material used to initiate the fracture (copper or antler) is mostly a matter of personal preference. The copper will require a stronger more heavily ground platform than the softer antler. And, if a massive flake is to be removed, more force can be applied using percussion instead of pressure due to the strength limitations of the person applying the pressure. If a mechanical levering device is used to apply pressure (such as in fluting), the flake removed should resemble that done by percussion. Again, the flake removed is primarily a result of factors 1 thru 4 above.

The bottom line is the stone simply follows the laws of physics and reacts according to the forces being applied to it. You cannot force a flake on a flat surface to be much longer than its width. You can, however, cause the flake to terminate short by applying pressure (such as with you fingers) to the surface of the flake as it is traveling. This usually results in a step fracture. I have heard of some knappers who are able to extend flake length by applying pressure along either side of the flake as it travels but I am not familiar with this technique and did not try it. My guess is that the flake might terminate short along the sides but continue straight ahead. It would be interesting to see what others are able to do using this or other techniques, and I’d really like to hear from them.

One final picture:

From http://www.flintknappers.com/oldsite/jim_winn_flat_surface.html, April 8, 2010, copied with permission

A Theory for Flake Creation
A Status Report of Research Begun April, 1997

Tony Baker

December 21, 2003

[Note: Many of the figures in the online version of this paper are animated and they obviously will not be in this hard copy. Indeed many figures have been left out of this hard copy because they are not very informative in static mode. Readers are encouraged to see the online figures.]

Introduction

In April 1997, I became interested in the mechanics of flake creation. I purchased some mechanical engineering software in 1998, modified it for my purposes, and began attempting to understand flake creation. Subsequently, I wrote status reports about my work in November 1998, September 1999, March 2000, and November 2001. Each report represented my understanding of flake creation at that writing. Each kept some ideas presented in the previous reports and, at the same time, contradicted some of the other ones. Such is the nature of discovery.

Until the fall of 2002, the only computer program that I was using in the research was the one I had purchased and modified in 1998. That program was a static model and, therefore, it only allowed me to investigate pressure flaking. I knew this, but since pressure and percussion flakes are so similar with the exception of size, I was not too concerned about it being only a static model. In the fall of 2002 Bill Watts, a colleague of mine from my Texaco years wrote a number of dynamic programs that allow me to start to investigate percussion flaking. In September of this year, I wrote another status report. Four days after going public with it, I realized there were some major errors in it. So, I quickly set out to correct those errors. I discovered it wasn't that easy. What I thought I could correct in two weeks took me three months. This is that corrected version.

To close this section, I want to thank Bob Patten, Andy Pelcin, and Bill Watts. Each of these individuals has been involved in this research almost since its inception.

Figure 1 -- Edge view of a 1" by 1/4" thick biface that is firmly supported on the opposite edge from the platform or the bottom in this Figure.

Vibration of Cores

Figure 1 represents a vertical, glass cantilever beam that is 1-inch long, 1/4-inch thick and firmly anchored on the bottom. (Click on Figure 1 if you haven't previously done so.) This cantilever beam can be visualized as representing a 1-inch wide, 1/4-inch thick biface core that is firmly supported at the edge opposite from the platform. If a force is applied to the platform of the core, it will bend as shown in Figure 2. In the real world this large amount of bending is impossible because glass is too brittle and will break. However, cores do bend when force is applied and the bending can be seen with magnification. Here the magnification is accomplished mathematically.

Figure 2 -- Edge view of a 1" by 1/4" biface. Biface is bent because a perpendicular force is applied to the platform. The deflection in magnified 15,000 times.

When the force is slowly removed from the core, it returns to its unbent shape, which is depicted in Figure 1. Again, Figure 2 is the bent shape and Figure 1 is the unbent or "at-rest-position" shape. If the force is removed instantaneously, the core will vibrate as in Figure 3. This vibration is identical to that of a tuning fork or a pendulum of a grandfather clock. Clicking on Figure 4 will cause the core to vibrate for only one cycle. Click on Figure 4 a few more times and watch the motion during one cycle. The thin, vertical black line in the middle of the Figure is the at-rest-position for the core. At the beginning of the cycle, the end of the core is on the right with no velocity. As it begins to move to the left and towards the at-rest-position it gains velocity. When it crosses the at-rest-position it has completed 1/4 of a cycle and is at maximum velocity. Past the at-rest-position, it begins to slow down as it continues to move to the left. At the far left, 1/2 cycle later, it stops and then begins moving back to the right, gaining velocity as it goes. Again as it crosses the at-rest-position, 3/4 cycle later, it is moving at its greatest velocity. Moving further to the right, it begins to slow down and finally stops at the far right and ends a single cycle. The time it takes this core to complete one cycle is 0.0004726 seconds, which is called the period of the vibration. Or, the core makes 2116 cycles in one second, which is its frequency. A frequency of 2116 cycles per second is well within the audible range of the human ear and, in fact, it lies within the range of the piano.

This period of the core does not vary with the amount of initial displacement. Figure 5 compares the vibration of the core for two different initial displacements. As can be seen, the time of a complete cycle is the same even though the red starting position is about half that of the black. This is extremely important because this means that the velocity of the end of the core is faster for the larger initial displacement. A pendulum on a grandfather clock behaves the same way. The period is independent of the displacement but the velocity is not. The period of the core is dependent on its shape, mass and material; removing flakes changes its shape and mass, and therefore its period. However, it does not change appreciably with the removal of a single flake so knappers are able to adjust their behavior gradually and subconsciously.

Pressure flaking is the application of a slowly increasing force. The force is applied so slowly that the entire core is able to bend or deflect in response to the gradually changing force. In different words, there are no inertia effects; the entire core and supports feel the pressure flaking force and respond to it. Figure 2 is an example of a load applied by pressure flaking. The entire core has experienced the force and the entire core has been deflected. Additionally, the amount of deflection is related to the amount of force that is applied. The more force, the greater the deflection. This is evident in Figure 5. The black response was created by mathematically applying a force twice that of the red response. It is the same core in each response.

So what determines how much force the knapper must apply to a core to initiate a crack when pressure flaking? Is it the muscles in his hands and legs? No, it is the platform. The platform strength determines how much force the knapper must apply to start a crack. If the strength is low, then little energy is added to the core and a short flake is the result. If the strength is high, abundant energy is added to the core and a long flake can result. Sometimes the platform strength is so high that the knapper can not overcome it and nothing happens.

Platform strength can vary for a number of reasons. If the platform is at an off-margin location, then it is stronger than a margin location. If the platform is on the margin, then platform preparation, such as grinding or polishing, determines its strength. Obviously, platform strength must not be too weak nor too strong, it must be just right. Therefore, it is one of several critical variables a knapper must manipulate while performing either pressure or percussion flaking. This is the reason Whittaker writes "platforms are the key to successful knapping" (1994:98). Patten concurs in his book with "preparing a stable platform is one of the most crucial skills a knapper can develop" (1999:39).

Figure 6 is an animation of the core in Figure 1 as the force is slowly applied to the platform. The force is applied at the location of the crosshairs and perpendicular to the platform face. The deflections are magnified 15,000 times. Click Figure 6 a couple more times and watch the movement of the platform. Also, note that at the end of the animation, the entire length of the core is experiencing deflection and this deflection is energy added to the core.

As stated above, if the force is gradually increased to the magnitude of the platform strength, then a crack initiates. In Figure 7, the crack initiation animation has been added. After the crack begins to propagate, the force needed to continue to separate the core from the platform is extremely small compared to that required to initiate the crack. To simplify this theory of flake creation, I assume this separation force is zero and the core is free to vibrate at its natural frequency.[1] Figure 8 depicts the creation of an entire flake with this assumption. Basically, the crack is propagated by the core pulling away from the platform. Click on Figure 8 as many times as necessary to determine movement of the core and platform during the creation of this flake.

The movement of the platform during the creation of the flake in Figure 8 is nil. This animation represents a rigid impactor or pressure tool, which means it does not move after the crack begins. This is an example of the crack being created with only the energy that is stored in the core. There is no additional energy or movement added by the impactor after the crack initiates.

With the previous assumptions of a separating force equal to zero and a rigid impactor, I can make a statement about the time it takes to make the flake or the speed of the crack. Notice in Figure 8, the crack finishes at the same time as the core returns to the at-rest-position. The time interval from the beginning of vibration (initiation of the crack) to the core reaching the at-rest-position is ¼ of the period (0.0004726 seconds) or 0.0001182 seconds. Since the core and therefore the crack are 1 inch long, dividing the length of 1 inch by 0.0001182 seconds can approximate the average velocity. This velocity is 215 meters per second.[2]

As stated above, a rigid impactor makes the flake in Figure 8 because the platform never moves after the crack initiates. Rigid impactors do not exist in the real world and can only be created in the mathematical world as I have done here. In the real world, impactors deflect (compress) as they apply force to the core just as the core deflects when force is applied to it. When the crack initiates, the impactor tries to return to its at-rest-position just like the core does. The result is the impactor pushes the platform away from the core and helps to propagate the crack. Figure 9 is an example of non-rigid, real world impactor creating a flake.

The only difference between the flake created in Figure 8 and the one created in Figure 9 is impactor stiffness. All the other parameters (angle of blow (AOB), platform angle, platform strength, etc) are identical. Figure 10 is an example of an impactor that is even less stiff than Figure 9, and again all the other parameters are the same. The flakes created in Figures 9 and 10 are feather flakes.[3] The reader probably has also noted that the more flexible the impactor, the shorter and thinner the resulting flakes and the larger the bulbs of force are. These observations are correct as long as none of the other parameters are changed. However, the knapper can change the angle of blow and create a full-length flake with either of the flexible impactors in Figures 9 or 10.

Defining the Static and Dynamic Loading Modes

Energy can be applied to a core in the static mode or the dynamic mode. In the **Vibration of Cores** section, the entire discussion concerned the static mode. Pressure flaking is done in the static mode. Some percussion flaking is also performed in the static mode and some in the dynamic mode. So what is the difference between the two modes? How are they defined?

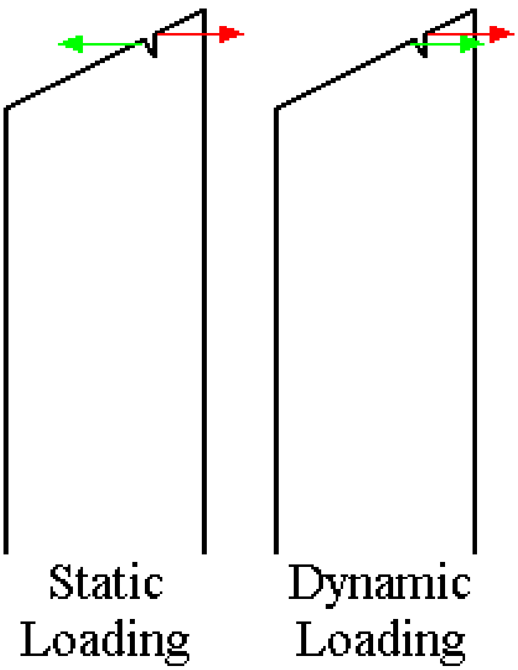


Figure 11 -- The motion of the core (not the flake platform) after the crack begins to propagate defines the static and dynamic modes. In the **static mode**, the core starts immediately towards its at-rest-position (to the left) when the crack begins. This is a result of the loading time being greater that the period of the core. In the **dynamic mode**, the core has a velocity in the same direction the flake platform is moving and, therefore, it continues in this direction when the crack begins. However, it immediately starts to slow down and ultimately reverses its direction towards the at-rest-position. This is a result of the loading time being less than or equal to the period. The green arrows represent the direction of movement of the core at the time the crack begins. The red arrows are the direction of movement of the flake platform.

The answer to these questions can be seen in Figure 11. Basically, the motion of the core, not the motion of the platform, at the time the crack begins to form defines the two modes. An immediate reversal of the core's direction toward the at-rest-position is static loading. If the core continues in the same direction after the crack starts, then it is dynamic loading. For animations of these motions see Figure 12 for static loading, and Figure 13 for dynamic loading.

The conditions necessary for each are:

Static Loading Mode -- Loading time is greater than the period of the core.
Dynamic Loading Mode -- Loading time is less than or equal to the period of the core.

The above definitions are based on the loading time of the core and its period. That said, I would like to introduce Figure 14 to further explore these modes. Figure 14 shows the loading regions for the 3" wide biface core in Figures 12 & 13. On the horizontal axis is loading time, which is part of the above definitions. However, the vertical axis is width-to-thickness ratio instead of period. I choose to use width-to-thickness ratio because it directly relates to the period and it is easier to comprehend. The period of a core is a function of its material composition (type of rock, which is constant) and its morphology (width and thickness). Since most knappers attempt to thin their cores while preserving the width, width-to-thickness ratio for a constant core width (in this case 3") is a good proxy for the core's period.

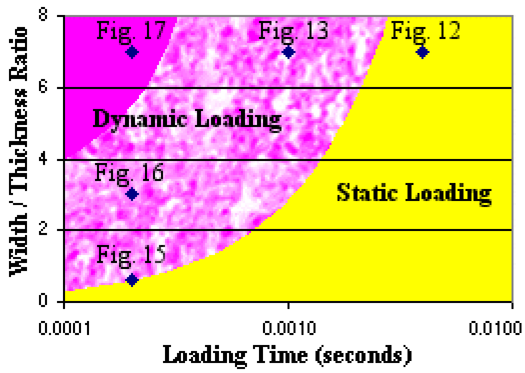


Figure 14 -- The loading regions of a 3" wide biface. The yellow is the static mode region and the purple is the dynamic mode region. The dynamic region is further subdivided into lighter purple and darker purple. In the yellow and lighter purple regions all the flake types except the hinge flake can be created. The darker purple is the region of hinge flakes caused by the second harmonic in the core's vibration.

I also wanted to use a more understandable proxy for loading time in Figure 14, but I could not find one. Unlike the period of the core, which is only a function of the core, the loading time is a function of platform strength, and the mass and stiffness of both the core and impactor. The knapper can't change the mass or stiffness of the core at any given stage, but he can definitely alter the platform strength. Additionally, he can change the mass and stiffness of the impactor. The most effective way to do this is to change the impactor's composition (rock, antler, bone, wood, etc.), size, and morphology (spherical, asymmetrical). To a lesser degree, the knapper can effect the impactor stiffness by varying the velocity of the blow and, in the case of asymmetrical impactors (billets), the attack angle can be altered.

Figure 14 also refers to Figures 15, 16, & 17, which are also cores with a width of 3 inches. However, their loading times are a constant 0.0002 seconds and their width-to-thickness ratios vary. With a loading time of 0.0002 seconds, it is very difficult to achieve static loading unless the core is extremely stiff. The core in Figure 15 is in the static region. It is 5 inches thick, which is a width-to-thickness ratio of 0.6. Conditions that this might represent are the earliest stages at the quarry where large irregular chunks are being impacted with spherical rock hammers of similar size.

Figure 16 represents a core a width-to-thickness ratio of 3 (1 inch thick) and is in the dynamic loading region. This width-to-thickness ratio is very common among the discarded cores at a quarry. Often these types are referred to as failures if one assumes they were on a reduction trajectory to becoming projectiles. (See Contrasting the Lithic Technologies of Mesa and Folsom.) These are also created with rock impactors that have similar masses as the core.

Figure 17 is the same core shown in Figures 12 & 13, which has a width-to-thickness ratio of 7. However, the loading time is five times faster than Figure 13, and 12 times faster that the core's period. The loading time is so fast in relation to the period that a strong, second harmonic has been introduced into the vibrating motion. Now the core actually reverses direction several times during its fundamental period of 0.00248 seconds. Click Figure 17 several more times and notice these reversals. These reversals cause hinge flakes, which are also very common at quarries because of the use of rock impactors. I will have more to say about hinge flakes in a later section.

Energy -- The Engine of Crack Propagation

Flakes are created because there is energy stored in the core prior to the crack initiating. The more pre-crack energy stored, the larger the flake can be. Figure 6 depicts the core bending prior to the crack initiating. This bending is the storing of the energy. Also, remember that platform strength determines when the crack initiates. As soon as the impactor force exceeds the platform strength, be it a pressure force or percussion force, the crack will start as it does in Figure 7.

Three variables determine how much pre-crack energy is added. These are platform strength, loading time, and the core itself. Strong platforms add more pre-crack energy than do weak platforms. Loading times can cause increases or decreases in pre-crack energy. Other variables being equal, flexible cores acquire more pre-crack energy than stiff ones. So how do these variables relate to each other in a manner that can be understood?

I struggled with this problem for several years. Finally, one day when all the celestial bodies happened to align just right, I discovered Figure 18, which is the normalized energy added to a core versus the normalized loading time. The two images in Figure 18 are the same, except the lower image is an expanded view of the red box in the upper image. The horizontal axis is normalized loading time (NLT), which is loading time divided by the period of the core. The vertical axis is normalized energy (NE) added, which is the pre-crack energy added to the core divided by the pre-crack energy added if the platform was loaded by pressure flaking. Figure 18 can be used for pressure and percussion. It can also be used for any size core that is supported on the far edge from the platform.[4] Finally, it applies to all platform strengths.

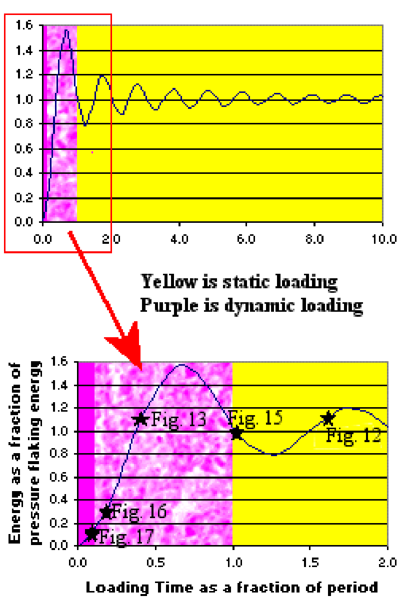


Figure 18 -- **Normalized Energy (NE)** versus **Normalized Loading Time (NLT)** of a biface with a constant platform strength.

A discussion of the curve in Figure 18 is in order to understand further its significance. Let's begin far to the right of the top image at a NLT of 1000.0 or so. A NLT of 1000.0 is a loading time 1000.0 times longer than the period of the core. This is the region of pressure flaking and the NE curve is flat at a value of 1.0. And, it should be because the pre-crack energy added by pressure flaking and divided by the same value is 1.0. This is the definition of the NE.

Moving to the left or to lower values of NLT in Figure 18, the NE curve begins to oscillate around the value of 1.0. At NLT around 10.0 this oscillation is between 0.97 and 1.03, which is insignificant in the knapping process. Continuing to lower values, the oscillating amplitude of the NE increases to significant values between 0.8 and 1.2 for NLT values between 1.0 and 2.0. At a NLT of 1.0, the NE is 1.0. Also, this is the transition between static and dynamic loading.

Crossing into the dynamic region where the NLT is less than 1.0, the NE added to the core increases to the peak value of almost 1.6 in Figure 18. This is 1.6 times the energy added during pressure flaking. This peak occurs at a NLT of 0.75. Then the NE curve starts to fall rapidly. It is back to 1.0 around a NLT of 0.5 and it is 0.0 and a NLT of 0.0

All the examples in Figure 14 plot on the NE curve in Figure 18. These five examples represent three different cores and three different loading times. Notice how Figure 18 separates and accounts for all these conditions.

Figure 18 is an explanation of the mathematical connection between pressure and percussion flaking. However, it can be misleading because the reader might think that percussion knapping occurs all along the NE curve. I don't believe this is the case. The knapping process begins at the quarry with a hard rock impactor and chunk of flakeable material. When I run values that represent these real world conditions in my computer programs, the percussion work always occurs at NLT values of 2.0 or less. I suggest that when the rankest rookie smashes two rocks together, the NLT is less than 2.0. The experienced knapper has learned to perform his knapping near a NLT of 0.75 with little variation from flake to flake. A NLT of 0.75 is the location of peak energy input into the core.

Removing each successive flake while maintaining a NLT of 0.75 is not easy, nor is it like shooting at a fixed target. Shooting at a fixed target requires the shooter to repeat everything exactly the same way from shot to shot. Flake removal is a moving target. It is a moving target because the period of the core is increasing as the core is becoming thinner. If the knapper repeats everything exactly the same way from blow to blow, he will be moving to the left in Figure 18. His flakes will change to step flakes because he will progressively apply less and less energy to the core with each flake removal. To compensate the knapper slows down his blow, which slows his loading time, and moves back toward the peak. However, ultimately the knapper will not be able to slow the blow any further because his impactor will have insufficient energy to exceed platform strength and initiate a crack.

The next thing the knapper does is subconsciously concede that he can no longer operate at peak energy input and increases his angle of blow (AOB), by moving the support or by selecting or creating a more acute platform angle. This larger AOB will cause the flake to feather out just before the crack would have stopped in a step termination. Additionally, he will select or create stronger platforms so he can still get an acceptable size flake. The effect of these two changes is to create feather flakes with strongly wedge shaped cross-sections. If these wedge shaped flakes are acceptable to the knapper, he will continue until the NLT value drops below 0.10+ and then short, unacceptable hinge flakes start to occur. At this point the knapper generally abandons the core or switches to pressure knapping.

The important point in the above scenario is that the impactor was never changed. If the impactor had been changed to softer material, such as antler, bone or wood, then the core could have been further thinned. A soft impactor changes the NLT value significantly. If a knapper was to change from a hard rock impactor that is operating at NLT=0.75 to a soft impactor and hold all other parameters the same, the new NLT value would be greater than 0.75. In fact, I don't believe a soft impactor deployed against a quarry chunk with a width-to-thickness ratio of approximately 1.0 can be made to operate at the peak energy input of NLT=0.75. Only when the width-to-thickness ratio of the core becomes larger will the soft impactor begin to operate at the peak value. When the soft impactor is operating at the peak, the hard rock impactor is making steps or hinges if all the other parameters were the same.

The Archaeological Record and Copper Impactors

The archaeological record from large quarry sites contains many bifacial cores that are whole and fragmentary. It has been my observation that these cores, regardless of the quarry location around the world, have two common traits. They have step and/or hinge flake scars and they rarely exceed a width-to-thickness ratio of 4.5. These cores are a signature of a quarry and I define them as quarry artifacts.

Quarry artifacts are the products of hard rock percussion on off-margin platforms. As discussed above the knapper begins the reduction of a chunk or spall of lithic material with a hard impactor and the NLT is in the range of 0.75. This is maximum energy input. As the core is reduced, the knapper doesn't change his impactor and, therefore, the NLT is decreasing. As the process continues steps flakes and ultimately hinges flakes start to occur. At this point the width-to-thickness ratio is still below 4.5. The knapper could change to a soft impactor (antler billet) and continue to reduce the core, but instead he chooses to abandon the core. The reason is that lithic material and hard impactors are abundant. Soft impactors are not abundant, and they are high maintenance tools in that they have to be continually refurbished and often replaced.

Away from the quarry, lithic material has a much higher value to the knapper. Now, the knapper will employ a soft impactor and choose platforms on the margin to conserve lithic material. By using a soft impactor, he can raise the NLT and further thin the core without step and/or hinge flakes occurring. With some skill width-to-thickness ratios of 7.0+ can be achieved.

Many modern knappers use copper impactors for their percussion work. Copper is closer to hard rock than it is to antler or wood, and therefore its NLT's are closer to hard impactors. It will yield step and/or hinge flakes sooner than soft impactors. Therefore, to avoid steps and hinges, the copper knapper will switch to pressure at an earlier stage of reduction (smaller width-to-thickness ratios) than the soft impactor knapper.

Final Remarks

The theory of flake creation presented in this web page has used biface cores in all the examples. This does not imply that it is not applicable to blade or other cores, because it is. The biface core is just a better textbook example because it passes through a wider range of flexibility than does the blade core. For example, I have observed that exhausted blade cores rarely exceed a length-to-thickness ratio of 2.0. However, as discussed previously, exhausted biface cores found at quarries (the quarry artifact) approach a width-to-thickness ratio of 4.5. Assuming that both blade and biface cores begin at a ratio of 1.0, bifaces are thinned twice as much as blade cores and, therefore, pass through a greater range of flexibility.[5]

Blade cores are so stiff in relation to the impactor that creating the second harmonic vibration in the core is almost impossible. That said, one would think it would be impossible to create hinge flakes on a blade core. However, look at Figure 19. This is a blade core with three ugly hinge flake scars. This probably happened because a soft, billet impactor was used (Jacques Pelegrin, personal communication 2003). Unlike the biface/hard hammer collision where the biface is the flexible member, the blade core/billet impact has the billet as the flexible member. Therefore, the second harmonic responsible for the hinge flake occurs in the billet and not in the core. This occurs when the blade core's mass is decreased to the point that the knapper has to swing the billet faster than normal and hold the core tighter than normal in order to get significant energy into the core (Jacques Pelegrin, personal communication 2003). The loading time is reduced and ultimately hinge flakes will begin to occur as in Figure 19.

Figure 19 -- A blade core with three hinge flake scars created by the vibration of the impactor. To create these hinge flakes, the impactor must be a long, narrow billet. The white arrows mark the termination of the hinge flakes.

The blade core in the image is from Les Maitreaux, a Solutrean quarry site in Central France.

Finally, the theory presented in this web page was derived from the output of several computer models, the archaeological record, and the products of the modern knapper. These three items had to be stitched together with logic and common sense and therefore, the theory may be partially or total incorrect. I sincerely hope someone attempts to test and challenge it.

References

Cotterell, Brain and Johan Kamminga

1987 The Formation of Flakes. *American Antiquity* 52:675-708.

Patten, Bob

1999 *Old Tools--New Eyes: A Primal Primer of Flintknapping.* Stone Dagger Publications, Denver.

Pelcin, Andrew W.

1996 *Controlled Experiments in the Production of Flake Attributes.* Ph.D. Dissertation, Department of Anthropology, University of Pennsylvania, Philadelphia. University Microfilms, Ann Arbor.

Whittaker, John C.

1994 *Flintknapping: Making & Understanding Stone Tools.* University of Texas Press, Austin.

Van Peer, Philip

1992 *The Levallois Reduction Strategy*. Monographs in World Anrchaeology No. 13, Prehistory Press, Madison.

Notes

[1] The assumption of a separation or propagation force of zero is obviously not correct because chemical bonds are broken as the crack is propagating and this requires the consumption of energy. However, after hundreds of FEA runs, it appears the energy to break the chemical bonds is very minute compared to the energy required to flex the core and overcome the platform strength.

[2] The average speed of 215 meters per second is too large because the calculation assumes the vibrating core thickness does not change as the flake is made. This is obviously incorrect. Look again at Figure 8. The flake being removed is reducing the 0.25-inch thick core to a thickness of 0.195 inches. This changes the period of the core vibration. A core that is uniformly 0.195 inches thick and 1 inch long will have a period of 0.0006059 seconds or about 30% longer. With this longer period, the average speed of the crack would be 168 meters per second. So the actual average speed of the crack in Figure 8 lies between 168 and 215 meters per second.

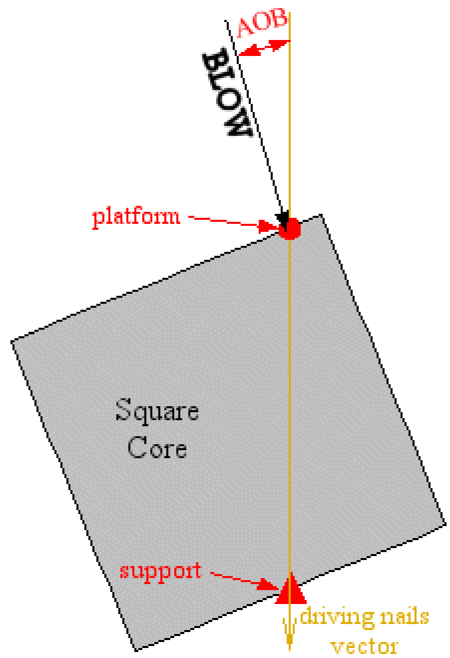
[3] In Figures 8-10, the computer program was stopped just before the next movement would have separated the flakes from the cores. The computer magnification greatly distorts the images.

[4] Figure 18 was derived from a mathematical model of a cantilever beam. A cantilever is a beam that is supported on only one end. A diving board is a cantilever beam. The biface in Figure 1 is a cantilever beam.

[5] Blade cores being thinned to only a length-to-thickness ratio ratio of 2.0, while biface cores are thinned to a width-to-thickness ratio of 4.5, suggests that less rock is wasted at the quarry with biface cores. This contradicts the old adage that blades yield more edge per pound of rock than biface cores.

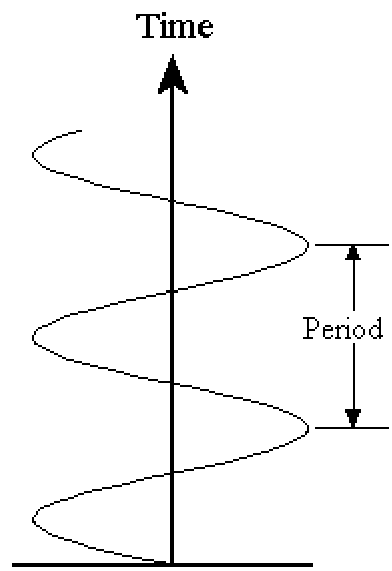
Definitions from "A Theory for Flake Creation"

Angle of Blow (AOB) -- I measure the AOB from the "driving-nails-vector", which is a line through the platform and the support of the core. This AOB is different from the one used by most authors (Pelcin 1996:83, Whittaker 1994:94), which is measure from the platform face. The significance of this difference is when I write, "increasing the AOB" it would be "decreasing the AOB" in the nomenclature of the other authors.



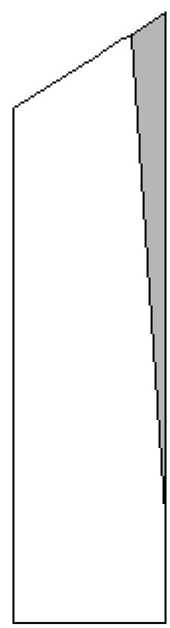
The driving-nails-vector is defined as the direction of the force that will not rotate the core. It will only compress the core. On large cores where the inertia of the mass becomes the support for the core, then the driving-nails-vector would pass through the platform and the center-of-mass.

I measure from the driving-nails-vector instead of the platform face because it makes the AOB independent of the platform angle. By separating the two, I can investigate the effects of one while holding the other constant. I have found that AOB is the dominant variable of the two with regard to their effects on flake morphology. However, since AOB is not preserved in the archaeological record, then platform angle is a good proxy for it since most off-margin strikes are perpendicular to the platform face.

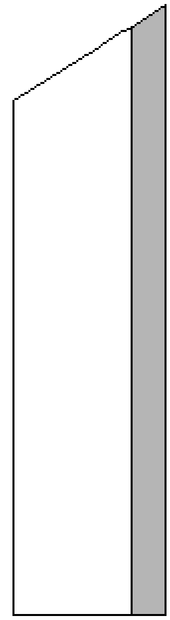


Cycle -- The motion that repeats itself in a vibrating system. A cycle is the vibration during the period.

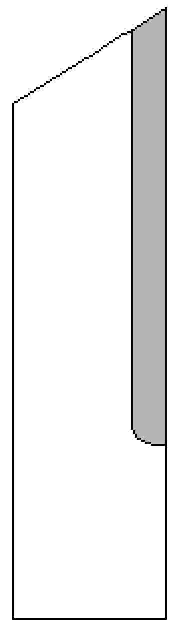
Flake Types -- I recognize the four common flake types of feather, hinge, overshot (or reverse hinge), and step that are found in most of the literature (Cotterell and Kamminga 1987:684; Patten 1999:85; Whittaker 1994:18). Plus, I add the full-length flake for a total of five. These types are defined by their crack trajectory and termination and not by their initiation. Each, with the exception of the hinge flake, can be created with either pressure or percussion (soft or hard hammer). Each can have the universe of bulbs of force. And, each can initiate under the force application tool or away from it (lipped flake). The factors that effect the creation of the various flakes are width-to-thickness ratio of the core, loading time of the force, and angle of blow.



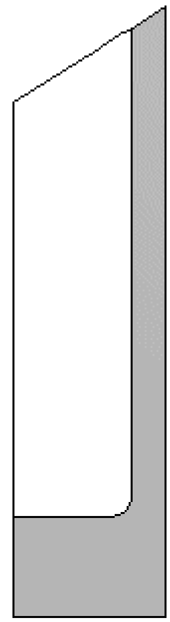
Feather Flake -- a flake created by a single crack with a straight trajectory that exits the front face of the core. Therefore, it is a fractional flake or is shorter than a full-length flake. When these flakes are removed from a flat face, they are wedge-shaped as in the image. The flake scars of these flakes can have some heavy ripples at the end, but the trajectory of the crack is still straight.



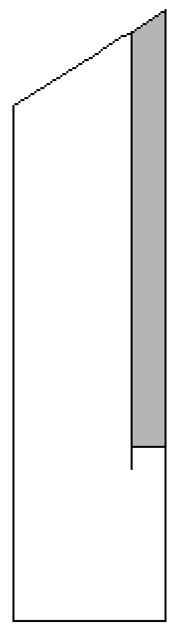
Full-Length Flake -- a flake created by a single crack with a straight trajectory that runs the full length of the core. As the crack approaches the far end of the core it will often turn, either toward front or back face, but it still exits the bottom of the core.



Hinge Flake -- a flake created by a single crack with a straight trajectory until it suddenly, but gently turns towards the front face and terminates the flake. It is a fractional flake or is shorter than a full-length flake. Often as the crack approaches the front face, but long after it has turned toward the front face, it will again turn either up of down. If it turns up it creates the classic lip (reflexed termination) that is associated with hinge flakes. If it turns down, then the flake scar (inflexed termination) is often assumed to be that of a feather flake with a jump in the scar surface. The hinge flake is the only flake that can not be created with pressure.



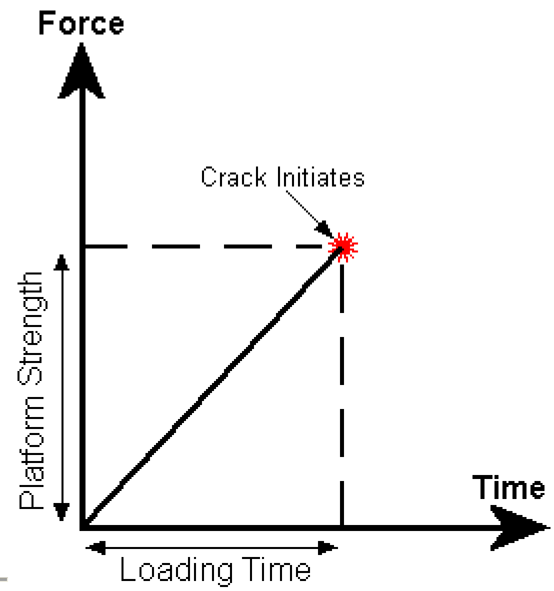
Overshot Flake -- or reverse hinge flake is created by a single crack with a straight trajectory until it suddenly, but gently turns towards the back face and terminates the flake. It has a trajectory that is the reverse of the hinge flake and hence, the second name "reverse hinge flake". It is a fractional flake or is shorter than a full-length flake.



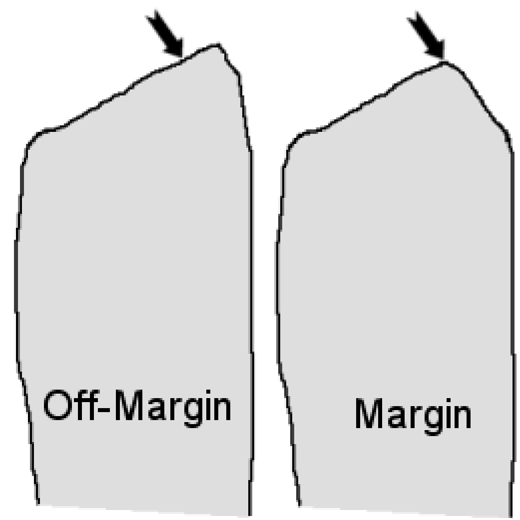
Step Flake -- a flake created by two cracks. The first crack is a straight trajectory that actually stops in the core because it consumes all the energy. When the first crack stops, a second crack caused by the knapper's follow-through breaks the flake off. It is a fractional flake or is shorter than a full-length flake. As in the drawing, evidence of the first crack extending beyond the end of the flake scar is almost always present because the second crack rarely begins at the very end of the first crack.

Length-to-Thickness Ratio -- Maximum length divided by maximum thickness.

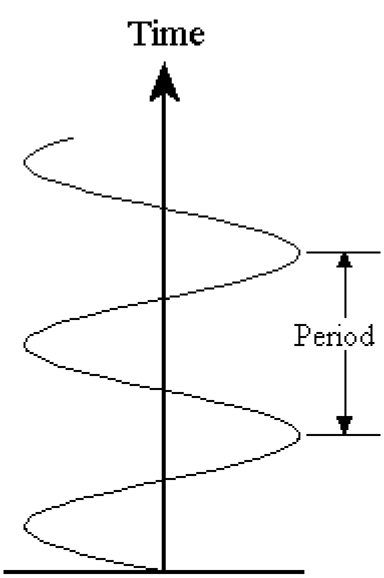
Loading Time -- The force application time it takes to raise the force on the platform to the platform strength. I assume the force increases linearly with time until the crack initiates, which is symbolized by the red star. After the crack initiates, the force on the core (not the flake) drops to zero.



Margin/Off-Margin Platform Locations -- Off-margin (off-edge) platforms are located away from the edge. Margin platforms are located on the edge. The arrows mark the platforms on the almost identical two cores. The difference between the two is the margin has been moved (reduced) in the core on the right. Margin platforms are usually associated with soft hammer percussion and pressure flaking.

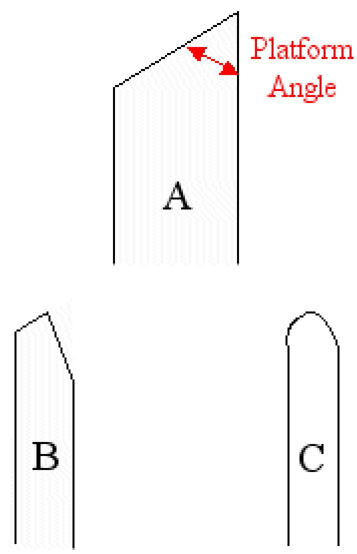


Period -- The time (usually measured in seconds) to complete one cycle of a vibrating system. The period is the reciprocal of the system's frequency.



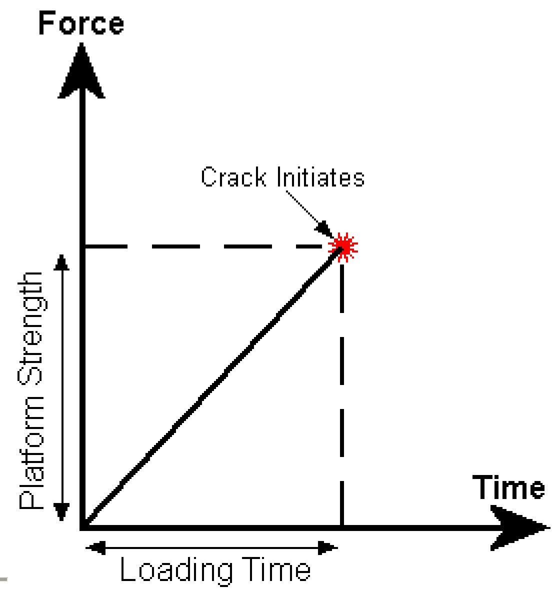
Platform Angle -- is the angle formed by the intersection of the platform face and the dorsal face of the core. See image "A". It is an easy variable to measure on a core and most research studies obtain this datum.

Platform angles are not as easy to measure on flakes. The flake in image "B" has an exaggerated reduced margin on the right edge of the image. Does one measure the angle between the platform face and the bevel that created the reduced margin or should one measured it from the true dorsal face? Image "C" is a flake created by a margin strike and the crack initiated at the point of impact, which removed all the platform face. Where does one measure the platform angle on this flake?

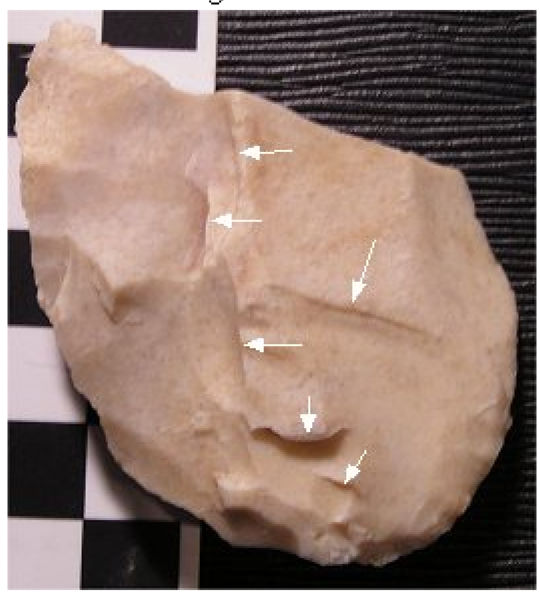


Most platform angles in the archaeological record range between 50 and 60 degrees regardless of time or space. For example, this range can be seen on Levallois cores (Van Peer 1992:24) or Folsom, channel flake preforms. When a platform is constructed (edge is turned) to remove flakes from a particular face of the core, it is done in a manner that minimizes the loss of the width or length dimension. The natural outcome of this minimizing effort is a platform angle between 50 and 60 degrees. Further support for this concept is the resharpening bevel on knives and points. These were hafted tools and the owner wanted to maximize their use life. So, they were beveled in a manner that minimizes the lost of material. The bevel on these tools is always between 50 and 60 degrees.

Many researchers have noticed relationships between platform angle and flake geometry. These same researchers also measure angle of blow (AOB) from the platform face, which couples the two variables (platform angle and AOB) and makes them dependent on each other. If angle of blow is measured independently of the platform face, the variation in flake geometry is a result of the angle of blow and not the platform angle. However, since AOB is not preserved in the archaeological record, then platform angle is a good proxy for it since most off-margin strikes are perpendicular to the platform face.



Platform Strength -- The force that must be applied to initiate a crack.



Quarry Artifact -- A bifacial artifact with step and/or hinge flake scars and a width-to-thickness ratio less than 4.5.

The biface fragment in the image is from an Archaic quarry in West Texas. The width-to-thickness ratio is 3.4 and the white arrows mark the termination of hinge flakes. It was purposely fragmented with a burin blow.

Reduced Margin -- See Margin/Off-Margin Platform Locations.

Width-to-Thickness Ratio -- Maximum width divided by maximum thickness.

From: http://www.ele.net/algor/flake_creation/SD_text.htm, accessed 6/7/10, copied with permission

The Ethical Responsibilities of Modern Flintknappers

Fisher, James V. (2003) “The Ethical Responsibilities of Modern Flintknappers”. *The Authentic Artifact Collectors Association Newsletter.* Volume 1, Issue 3.

True or false: *All who engage in modern flintknapping are evil-minded con artists who intend to commit fraud, compromise the archaeological record, and complicate the market for authentic relics*. If you answered true then read no further. If you answered “false” then perhaps you are counted amongst the many collectors with a simple desire to try your own hand at making the types of stone tools you have been finding in fields and creek beds since childhood. You may also have answered “false” if you are one amongst many collectors of authentic relics who has developed an appreciation for the knowledge that can be gained through participation in modern lithic studies involving stone tool reproduction.

I believe that at one time or another most collectors of authentic relics have puzzled in admiration over the methods and techniques that our prehistoric American inhabitants employed to create such lithic treasures. A natural curiosity about the means by which projectile points were made often leads collectors to experimentation and involvement, at variant levels, with flintknapping. The purpose of this article is to offer some advice to collector/knappers that will help to ensure that your endeavors do not lead to further complications in the market for authentic relics, a compromise of the archaeological record, or indirect and unknowing involvement in a third-party transaction where a fellow collector has been subject to outright fraud.

Generally, flintknappers can be divided into three categories, commercial knappers, academic knappers, and hobby enthusiasts. For individuals who engage in flintknapping as either a hobby, academic, or commercial endeavor it should be understood that an ethical responsibility of the highest regard is warranted. I propose a maxim by which all modern flintknappers should abide: *I shall not engage in the production, sale, or trade of reproduction artifacts unless measures are taken to clearly identify and permanently mark them as modern reproductions.*

It is in the interest of setting apart modern reproductions from ancient authentic relics, that the phrase “*clearly identify and permanently mark*” comes to bear. Modern flintknappers must assume the ethical responsibility of taking reasonable measures and precautions that will ensure that the products of their activities are never co-mingled with, or presented as, authentic prehistoric artifacts. That task is far easier said than done. What follows are some suggestions for clearly identifying and permanently marking reproduction artifacts, whether you produced them or acquired them. If you are new to knapping or have not yet committed to marking your work on a regular basis, you might benefit from some additional, friendly advice on how to accomplish this effectively.

Just as serial numbers on guns can be eradicated, so can most attempts to "permanently" mark reproduction points on their surface. With that being said, a very effective, yet perhaps less widely accepted suggestion is for a hole to be drilled completely through a modern point with a diamond tipped drill. There is no argument that this would, in conjunction with additional measures, clearly identify and permanently mark the reproduction as such. Even the most ethical and well-intended knappers (myself included) are not going to be thrilled about drilling a hole completely through their work. Many modern flintknappers and collectors of modern reproductions regard lithic creations and replica points as art and are hesitant to employ a method of clear identification and permanent marking that substantially detracts from the finished point.

What can and should we *reasonably* expect from modern flintknappers? I personally like the idea of using a diamond tipped scribe or high-speed diamond drill bit to mark reproduction pieces. It is as responsible and permanent an effort as can be reasonably expected. Signing (or initialing) and dating reproductions with a diamond scribe is best done nearer the center of a point where it would be more difficult to remove the mark via additional flaking. I also recommend placing additional markings on the point with permanent black pigment or India ink that has been subsequently coated with clear nail polish. It is not always easy to readily see signatures or markings made with diamond tipped scribes on certain lithic materials. The use of pigment ink will offer a second, more prominent marking that can make the overall effort of clear identification more effective. Individuals who sell modern points are encouraged to mark them with the phrase “Reproduction-For Study Only”. While this may not always be practical, particularly on smaller points, a simple “R” would likely suffice when accompanied by a diamond scribed signature (or initials) and the year of manufacture.

The next suggestions for ethical responsibility have more to do with what becomes of a modern reproduction after it has been clearly identified and permanently marked as such. It is imperative that if you choose to sell your modern work that you do so to individuals who can be trusted to continue the responsible custodianship that you have shown. In short, sell nothing to individuals whose motives for buying reproductions may be suspect. I have unfortunately known flintknappers who sold their reproductions to an unknown buyer only to find them listed in the “authentic artifacts” category on a popular online auction site. The modern points were quickly aged and presented as authentic by an unscrupulous dealer only days after they were obtained.

Modern knappers must also be concerned about those reproductions that will never leave their possession – during their life time. Non-commercial hobbyist knappers must also take reasonable steps to clearly identify and permanently mark their creations as modern. Keeping a meticulous record of reproductions in your collection complete with unique catalog numbers can help future heirs to easily distinguish modern reproductions from authentic ancient relics. All knappers must assume an ethical responsibility for clearly identifying and permanently marking creations that are sure to remain intact for countless generations to come.

Unfortunately, unethical knappers and fraudulent dealers will continue to flaunt any suggestions made concerning the management and identification of reproduction artifacts. The purpose of this treatise was to simply further the expectation that all ethical individuals who are involved with modern flintknapping will do their part to ensure the long-term viability of the authentic artifact collecting hobby and the integrity of the archaeological record.

From http://www.creeksideartifacts.com/Ethics/knappingethics.htm, March 31, 2010, copied with permission

FLINTKNAPPING AND SILICOSIS

by J. Kalin (orginally published in Flintknappers' Exchange 4(2): 1981)

Introduction

Could early man have been a victim of an industrial disease?

I believe this to have been the case.

Flintknapping, an activity that dominated more than 99% of the archaeological record of human evolution, turns out to be potentially dangerous to the health of the flintknappers. The process, which involves the breaking of siliceous rocks, produces a fine dust. Repeated inhalation of the free silica particles (Si02) can lead to a pneumonic condition called silicosis or fibrosis. This problem has also been noted by workers in mining, sandblasting, stone carving, road construction and ceramics, where silica is a major cause of pneumonoconiosis or occupational lung disease (Agrecola 1557; Arlidge 1882; Collis 1915; Hunter 1978; Middleton 1930; Oliver 1902 and 1916; Ramazzini 1713; Severo 1980). Prolonged exposure to silica dust particles increases the chance of developing severe silicosis. When microscopic particles are inhaled they pass into the lungs by way of the trachea branching into the two main bronchi. The bronchi, in turn, branch into many tubes which continue to branch repeatedly until each finally terminates in an elongated saccule, the alveolar duct. Branching off this saccule are millions of tiny globular sacs or alveoli. The openings into these sacs are very small, about 5-10 microns. It is in the alveoli that gas exchange takes place with the blood. Our lungs contain approximately 750 million alveoli, which explains why the interior surface area of our lungs is more than fifty times that of the skin of our bodies.

Our bodies provide a defense of filters to protect our lungs. The hairs and sinuses of the nose catch the initial dust. The trachea and the larger branches of the bronchial tubes are covered with mucous cells and cilia which protect and clean the lungs of the finer particles. Mucous traps the particles while the beating of the cilia removes dust-laden mucous from the lungs.

Problems arise because silicates can break into very small particles, much smaller than 20 microns. These minute flakes enter the deepest part of the lungs, past the mucous and cilia cells in the bronchae and continue until they reach the alveoli, or air transfer sacs. Once these flakes become lodged in the alveoli, they cannot be removed by the lung's natural defense mechanism.

The condition becomes more and more serious as the alveoli fill up with razor sharp particles, although the effect is often not felt for many years (usually after 10 to 25 years according to Plunkett, 1976, and 20 to 30 years according to Berkow, 1977).

How Silicosis Develops

Silicosis develops through three recognizable phases (Hunter, 1978; Middleton, 1930). In the beginning the most important symptom is a slight difficulty in .breathing which becomes apparent after exertion, increasing in severity as the condition progresses. A cough may also develop, which is usually "dry", with little mucous. Generally, because (: of the gradualness of the process, individuals feel little immediate effect from the changes taking place in their lungs. Fibrous tissue develops around the dust ladened cells and form:; small round nodules, several millimeters in diameter. These become a permanent part of the lung tissues and are visible by x-ray analysis.

Coughing and shortness of breath become noticeable in the next stage. Nodules increase in size and number, occasionally lumping together into conglomerates. Sounds can sometimes be heard in the lungs. A reduced chest expansion, high blood pressure and noticeable effects on working ability are also symptomatic.

During the final stage, the dehabilitating effects of the condition are accentuated nodular development, emphysema, and x-ray evidence of growing fibrous masses of tissue. These cause extensive incapacitation of the victim and may ultimately result in death.

In addition to the lacerating sharpness of the tiny flakes, a chemical reaction must take place for silicosis to occur (Hunter 1978; Kettle 1932). A soluble substance called silicic acid dissolves off the surface of the stone and polymerizes when it is neutralized by the body tissue. (In polymerization, molecules combine to form long chain compounds of a high molecular weight. This type of reaction is used to make polyethylene or common plastic.) During its creation, polysilicic acid poisons the surrounding tissues. The affected cells appear to be mummified and do not decompose as dead cells in the lungs normally do. What makes flint and quartz particles among the most dangerous of all mineral dusts is the extent to which they dissolve into the blood plasma and the low pH of the acid produced (Hunter 1978). The fibrosis is caused by a poorly understood reaction from the interaction of silica by-products with lung macrophages or defense cells (Cullen 1980). This can be illustrated by comparing flint dust to cement dust which is also high in silicic acid. The high alkaline pH of the limestone in the cement neutralizes the acid and renders it harmless before it reaches the blood plasma and body tissues (Hunter.978).

Types Of Quartz

Some types of quartz dust are more dangerous to inhale than others (Cullen 1980; Stober 1966). There are three major types of silica deposits which constitute the majority of knappable stones: Amorphous, common quartz crystal and cristobalite. Cristobalite is a cubic crystal that forms at high temperatures and is less prevalent than amorphous and common quartz. A fourth type, tridymite, is rare and only encountered in minute traces.

The least dangerous, but by no means safe, is the amorphous type which is a quick cooling, crystal free variety. Glass, obsidian and opal are examples of amorphous quartz.

Common quartz and quartzite are examples of quartz crystal. Also included in this group are chalcedony, flint, jasper, and chert, all of which are microcrystalline and possess microscopic needle or fiber-like quartz crystals, often arranged in fan-like structures.

Composition Of Flint

Most flints are composed of 98% silica with 1% to 2% water and minute quantities of impurities which cause color variation. The water appears to be responsible for the exceptional tensile strength of the material (Shepherd 1972). The needle-like, microcrystals of quartz may vary in size and shape from the shorter, stouter type, like those in Irish gray flint, to the long slender crystals found in English black flint. Not all flints are common quartz. Amorphous quartz, cristobalite and tridymite may occur adventitiously also. In Danish flint, which is visually similar to English flint, common quartz was found to range between 4% and 100%. The remainder of its composition was made up of cristobalite, glassy quartz, or a mixture of the two (Shepherd 1972). Traces of tridymite were also found in several samples. Cristobalite has proven t6 be the most dangerous of the silica dust and workers exposed to cristobalite display a higher incidence of silicosis (Cullen 1980). Cristobalite may also be found in rhyolite, bentinite, obsidian crystal pockets, high fired ceran1ics, and basalt.

Diagnosis Of Silicosis

Silicosis is easy to diagnose in its early stages by x-ray and the individual can take appropriate steps to avoid the dehabilitating and irreversible effects of the advanced stages. An obvious step is to stop exposure to silica dust. Continued exposure will aggravate one's silicosis condition, but there is a difference of opinion as to what happens when a person with silicosis symptoms is no longer exposed to silica dust. In severe cases, it appears the disease does not arrest itself. However, evidence from several studies in England show that when people with early silicosis discontinue their exposure to silica dust, either the disease does not progress, or its development is retarded for a considerable number of years (Middleton 1930; Board of Trade 1945).

Additional Complications

Curiously, rheumatoid arthritis sufferers show a high rate of incidence of previous exposure to silica dust. This may be explained because silica-ladened white blood cells often re-enter the blood stream from the lungs and thereby transport particles to other lymphatic areas of the body (Cullen 1980). In 1885 Arnold found silica particles included in the liver, the spleen and bone marrow (Arnold 1885). Cuts from knapping may also leave slivers of stone in the body.

It also appears that smoking increases the danger of silicosis. Be it today, or in ancient times in the New World, nicotine paralyzes the cilia and prevents the natural cleansing of the bronchial tubes, which results in the bigger flakes being retained.

Carving soapstone may cause mesotheleoma (a cancerous lung disease) due to the asbestos fibers in the stone. While silicosis and cancer are found together, there is no proven evidence that silica is a carcinogen (Hunter 1978). In the last year or two, some evidence suggesting silica related cancer has been emerging (Cullen 1980).

Ironically, even black lung disease, common among coal miners, is attributed not so much to the coal itself, but to the silica dust present in the coal (Shottenfield 1980).

Tuberculosis often accompanies silicosis and the result is a devastating combination. Since it is the most frequently associated complication, tuberculosis plays an important role in silicosis history (Hunter 1978).

Capable of infecting other animals (cows, for example) as well as humans, the roots of tuberculosis have been traced back thousands of years in Africa, Asia, Europe, and North and South America. Examples of tubercular disease and deformation have been identified through autopsies of ancient mummies, "deformed bones (Potts disease) and may be seen depicted in examples of prehistoric art work (BrothwellI968; C. Wells 1966; Ritchie 1952). Silicosis has been identified in mummies from Egypt (Harris 1978) and Peru.

It is very difficult to differentiate between silicosis and tuberculosis by x-ray alone, and diagnosis should not be made unless additional tests are run. Even in autopsy, the two lung diseases tend to obscure one another, making diagnosis very difficult (Hunter 1978).

TABLE I

RELATIONSHIP OF DEATHS FROM TUBERCULOSIS TO QUARTZ CONTENT OF DUST*

OCCUPATION	QUARTZ CONTENT OF DUST	PERCENT DEATHS FROM PULMONARY TUBERCULOSIS
FLINTKNAPPERS (Brandon, Eng.)	100%	77.8%
GRINDERS (Sheffield, Eng.)	50% - 100%	49.7%
GRANITE-CUTTERS (Maine and NH)	30%	47.8%
POTTERS (Certain Processes Only)	28%	18.9%
COAL MINERS	--	9.8%

* After Collis

There is a direct relationship between the silica content of and industrial dust and workers' deaths from pulmonary tuberculosis. The 1913 study by Dr. E. Collis showed that over three quarters of the flintknappers at Brandon, England died of this problem. He was able to show that workers with silicosis are more prone to contracting tuberculosis and more susceptible to infections from other types of pathogens. Even relatively harmless dusts, when inhaled by a person with mild silicosis, may create a potentially serious pneumonoconiosis condition (Collis 1913). His research concluded that the more different a substance is from those of which the body is naturally composed, the more injurious it is to the body.

In light of this information, how can we flintknappers protect ourselves from these dangers?

The Dangers Of Working Indoors

In 1930, Middleton measured the atmospheric dust produced by two flintknappers working in a shed. His findings showed concentrations as high as 1,313 particles per cubic centimeter, with the majority of the flakes under 1 micron in size. Only 2% of these tiny flakes were over 2 microns. These minute particles easily enter the 20 micron alveolar sacs of the lungs, making silicosis complications from flintknapping understandable. Remembering that a micron is only one thousandth of a millimeter helps you visualize how small these flakes actually are. By definition, particles smaller than 1 micron cease to be called dust and are classified as fumes and those smaller than .3 of a micron are listed as smoke. Imagine the particle counts at a modern indoor knap-in. Errett Callal1an spoke of seeing clouds of dust at the Flintknappers' Exchange 1979 Knap-in at Casper, Wyoming (E. Callahan 1980).

During the winter I maintain an indoor workshop in the basement of my house. Since the ventilation is poor, 'I now wear a respirator while working. The Mine Safety Appliances Company in Pittsburg, Pennsylvania makes a mask for dust and fumes that does the job, It is a COMFO 2, custom respirator with a filter cartridge for asbestos-containing dusts, fumes, and mists. While no filter gets everything, the filter meets Mine Safety and Health Administration (MSHA) and National Institute for Occupational Safety and Health (NIOSH) safety requirements. A mask with dual filter cartridges should cost about $20. The cartridges may be' used until they become clogged with dust before changing, but care must be taken not to let the interior of the mask become contaminated with silica dust when it is not being used. To prevent this, I fasten plastic sandwich bags around the cartridges with rubber bands. Be sure to wear your mask while sweeping up debitage. When working indoors, remember it takes over a half an hour for suspended silica dust and fumes to settle (Middleton 1930).

An exhaust fan will also prove useful when working indoors.

Clothes worn while knapping should be changed, or at least brushed off, after working to avoid tracking dust into living and sleeping areas. Another possibility would be some type of knapping apron to protect clothing from dust. Use of a particle ionizer will also reduce exposure to small particles (electrostatic precipitator).

Working Outdoors

Unless a wind is present, I try to wear a mask while working outdoors, especially when the work is very dusty. When working without a mask, I try to sit so that the wind aids in dust removal. I also try consciously to time my breathing to avoid inhaling the clouds of dust I have just produced, whether from quarrying the stone or finishing a biface with pressure. Fine dust forms whenever the stone is broken. For example, I have found that my platform preparation technique of shearing/abrading tends to produce a lot of visible dust. This can easily be seen when viewed by a strong side light against a dark background. You will notice that while the tiny flakes fall to the ground, a smoke-like powder floats upward, where it is easily inhaled/ Because of this, when I work without a mask, I try to avoid inhaling whenever I see dust while abrading. I hold my breath or slowly exhale, blowing a fine stream of air across my platform. This helps to get the dust away from me so it can be dispersed and removed by air currents.

Incidentally, most of the disposable dust masks for sale in hardware and paint stores provide only limited protection and arc inadequate for filtering the suspended silica dust and fumes produced by knapping.

Historic

Silicosis is the oldest ~known occupational lung disease (Berkow 1977). Historically, the use of dust masks for flintknapping begins in Brandon, England, where gun-flint knappers wore sponges tied under their noses in an effort to prevent the devastating effects of Phthisis or "knappers rot" (Shepherd 1972). Historically the flintknappers of Brandon, England, still a knapping center, suffered a high mortality rate from silicosis, often with tubercular complications (Collis 1913, 1915). Working mostly in sheds, skilled knappers, who could make three thousand gun flints a day (Webb 1911), were not expected to live much more than forty years (Collis 1913 and 1915; Middleton 1930; Shepherd 1972). The Table (Table II) by Edgar Collis, Medical Inspector for Factories in England, shows the death rate for Brandon Flintknappers. We are most indebted to him for his research.

Notice that wives of flintknappers and others not engaged in the profession were not affected by silicosis and had normal life spans. Agrecola (1557) noted that wives of Carpathian miners had as many as seven husbands, due to the high mortality rate among the miners from silicosis.

In the "Minutes of Evidence", Collis describes in detail several of the flintknapping families. At the time the study was made, in one family of twenty-six persons (thirteen males and thirteen females), twelve of the males had been flintknappers and ten of them had died. This left two flintknappers and the one 'non-flintknapping male alive, while all thirteen of the women were still alive. In another family of six males, three became flintknappers, Two died leaving one flintknapper and three non-flintknappers alive. In a third family, two of the six males became flintknappers, and only one was still alive to join all four of the non-flintknapping males still living. Collis concluded by saying, "Despite the size of this small industry, there is an excessive mortality problem,"

In modern Brandon, Mr. Fred Avery, the last of Brandon's flintknappers, said that in an effort to avoid silicosis, he tries to work in a well-ventilated room and limits his knapping to 1-1/2 hours per day. Avery said that because of the historic instances of silicosis and its recorded high mortality, parents in the town discouraged their children from learning to knap (Gould 1980).

In France, among the people of the town of Meusenes, the gun-flint industry produced results similar to those at Brandon, England. Chateauneuf said, "By a fate, which seems connected with all that concerns the art of war, this industry slays those who follow it; it kills them before their time; for them there is no old age." When asked the cause of so premature a mortality, doctors and officials gave the same reply-pulmonary phthisis induced by prolonged inhalation of dust generated from working flints" (Collis 1915).

TABLE II

COMPARING THE MORTALITY FROM PHTHISIS OF FLINTKNAPPERS WITH THAT OF CERTAIN OTHER CLASSES*

	ALL CAUSES	CAUSE OF DEATH, STATED AS PERCENTAGES FROM PHTHISIS	RESPIRATORY OTHER THAN PHTHISIS	ALL OTHER CAUSES	TOTAL DEATHS	AVERAGE AGE	DEATH[1] RATE PHTHISIS
FLINT - KNAPPERS[2]	100.0	77.8	7.4	14.8	27	46	41.0
WIVES (2) AND WIDOWS (11) OF KNAPPERS	100.0	0.0	15.4	84.6	13	78	0.0
BRANDON RURAL[3] DISTRICT	100.0	6.5	11.7	81.8	63		0.8
ALL MALES[4] (ENGLAND AND WALES)	100.0	11.2	17.6	71.2	509,567	Median 56-57	1.6

1. Death rate from Phthisis per annum among 1,000 living.
2. Average number employed for 25 years estimated at 16.5.
3. The figures for this class supplied by Dr. A. Harris, M.O.H., Thetford, Norfolk, are for all ages, 1901-1910.
4. The figures for this class, calculated from the Supplement to the Sixty-Fifth Annual Report of the Registrar General for all males aged 15 upwards, 1900-1902.

The average age at death of the 21 flint knappers who died from phthisis was 42.3 years, which is rather higher than the median age at death - between 39 and 40 - of all males dying from phthisis. The immunity of wives and widows of flint workers (see Table II) is also found among the families and relations.

Conclusion - as far as this small industry is concerned, exposure to fine dust of pure silica causes an excess mortality from phthisis, not found ill the neighborhood in which the industry is carried on, nor among workers' relatives who do not carry on the industry.

E. Collis, M.B. H.B.
MEDICAL INSPECTION
OF FACTORIES

*From the Royal Commission Report on Metalliferous Mines and Quarries, 1914, page 262 Appendix J.

Industrialization is probably responsible for these problems among the gun flintknappers, for it is from the continued exposure to silica dust that most cases of silicosis occur. If this is so, one would expect that this early industrial disease extended back into the Paleolithic period (Brothwell 1968; Wells 1964; Brothwell and Higgs 1969). Archaeologically; it might be possible to identify it in burials by analysis of the silica content in the dirt in the chest cavity compared to the surrounding soil. Biopsies of lung tissue in mummies could provide valuable data (Harris 1978). By Neolithic times extensive flint mining operations were taking place in northern Europe, and flints were dug and worked by the ton (Bosch 1979). Much of this flint went into making axes, which were often pecked and ground smooth for completion. These processes, if done without water, would produce excessive quantities of dust. Also, if water had been used and then was permitted to dry in the work area, it would allow flint dust to become airborne.

Thomas Benson, who in 1713 invented a method for wet grinding flints, states in the patent that the process of dry grinding "proved very destructive to mankind insomuch that a person ever so healthful or strong, working in that business, cannot possibly survive over two years, occasioned by the dust sucked into his body by the air he breathes" (Royal Commission, Vol. 1, Pg. 134).

Other Causes of Silicosis

While industrialized production of stone implements took place in different societies, not all silica workers could be considered flintknappers. Great numbers of craftsmen were exposed to dust as they carved out monumental statues and other constructions. In 1869, Hugo Millers wrote, "The mason is almost always a silent man; the strain on his respiration is too great when he is actively employed to leave the necessary freedom to the organs of speech" (Royal Commission, Vol. 11914).

Exposure to volcanic dust after eruption may also cause silicosis. The effects of exposure to high silica ash from Mt. St. Helens should become evident in the coming years (Severo 1980). Throughout time, volcanic eruptions covered different areas of the world with huge amounts of high silica ash. In some places the ash fall was so great that it buried whole cities, such as Pompeii or Thera, or caused entire populations to move, such as the Maya (Trotter 1977).

Silicosis also affected workers in the ceramic industry (Arlidgc 1892; Oliver 1902 and 1906). Flint glazes, mixing dry clay and sweeping up the powdery residues are probably the most dangerous activities.

In PreColumbian Mexico and Central America and in the Middle East, large specialized knapping centers developed to serve the elaborate obsidian trade networks that traded blades, bi-faces and ground stone objects. Through chemical-stone analysis it has been possible to trace how specialized craftsmen work daily in special quarry towns to make tools for people hundreds of miles away (Flannery 1976; Dixon 1968). In both these areas of the world, industrial stone knapping still exists today. For example, in the town of Teotehuecan, just north of Mexico City, craftsmen make percussion flaked spear points (projectiles) and carefully carved and polished obsidian objects. These are decorative rather than functional products, manufactured for the tourist market which has carried many of these items as far as Europe, Australia, and Asia (personal observation).

Stone tool making on a functional basis can be seen today in northwestern Turkey. Here professional flintknappers make direct percussion blades used in threshing sledges during the wheat harvest. A good knapper can manufacture almost 500 pounds of blades a day if the flint has been quarried beforehand. A village can produce about 500 tons a year. The blades are sold to merchants who distribute them throughout the country (Bordaz 1968).

Clearly, in these specialized occupations, workers are exposed to excessive quantities of silica dust and occupational lung disease could result. I am unaware of any medical study that has been done on the flintknappers of Turkey or the obsidian workers of present day Mexico, but these would be prime groups to investigate for signs of pneumonoconiosis.

Today, unfortunately, many of us find ourselves in a similar situations as we work daily making lithic artifactual replications and the like. Whether for scientific research, pleasure, or commercial production, we have become industrial craftsmen who subject ourselves to excessive amounts of silica dust and the inherent dangers.

The questionnaire which follows is an attempt for all of us to find out more about ourselves and flintknapping. Once the data is compiled, the results will be made available in a future issue of

Flintknappers' Exchange. The Brandon history need not repeat itself today. By increasing our understanding and awareness of these potential hazards, we should be able to take appropriate steps to protect ourselves against unnecessary pulmonary damage.

Summary

Silicosis is caused by the life-long exposure to and accumulation of free silica dust (Si02) in the lungs. Its degree of severity appears to be directly related to density, length of exposure, particle size and type of quartz. The effects are often not felt until many years after exposure. The best way to prevent silicosis is to minimize the inhalation of suspended silica dust. While knapping, this may be accomplished by working outdoors and by wearing a respirator mask. If you are an avid knapper, a respirator would be an important part of your tool kit. Even if you only wear your mask for the more dusty operations, every little bit helps. When working without a mask, try to time your breathing to avoid inhaling the dust. Changing or brushing off your clothes after knapping may also prove useful. Where possible, water should be used when grinding silicates.

It is strongly recommended that knapping not be done indoors or in poorly ventilated areas unless a respirator is worn.

The last few issues of Flintknappers' Exchange (Volumes 3:1 and 3:2) showed pictures of indoor flintworking with windows shut. In many ways this simulates a prehistoric mining operation, lots of dust and little ventilation, and may be considered very unhealthy and dangerous. Realizing that health problems can arise from flintknapping is only half the battle. We must each take responsibility for taking precautions and changing old habits, to protect our own lives and the lives of those whom we introduce to the art. By taking the necessary precautions, we will be able to continue knapping to a ripe old age, free from the fear of silicosis.

I wish to express my appreciation to Errett Callahan, Mark Cullen and Denise Tratolatis for their generous efforts in making this paper possible.

Bibliography

Agrecola, G., 1557 De Re Metallica. Froben Basil

Arlidge, J.T., 1892 The Hygiene Diseases and Mortality of Occupations. Percival and Company, London.

Arnold, J., 1885 Staubinhalation und Staubmetastase. Berlin, Germany.

Berkow, R.,1977 The Merck Manual. Merck and C,)mpany, Rahway, New Jersey.

Board of Trade, 1945 Provision of Employment in South Wales for Persons Suspended From Mining Industry 0~1 Account of Silicosis and Pneumonociosis. Board of Trade, His Majesty's Stationary Office, London.

Bordaz, J., 1969 "Flint-Flaking'in Turkey." Natural History Magazine,78:73-79.

Bordaz, J., 1971 Tools of the Old and New Stone Age. Natural History Press, Garden City, N.Y.

Bosch, P.I.,1979 "A Neolithic Flint Mine." Scientific American, 240(6):126-132.

Brothwell, D., 1968 The Skeletal Biology of Earlier Human Populations. Pergamon Press Ltd., London, England.

Brothwell, D. and Higgs, E., 1969 Science in Archaeology. Praeger Publishing, Inc. New York, New York.

Callahan, E., 1980 Personal Communication.

Collis, E., 1913 Annual Report of the Chief Inspector of Factories .

Collis, E., 1915 Public Health, Volume 28, pp 252-264.

Cullen, M., 1980 Personal Communication.

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