Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Fig. 19

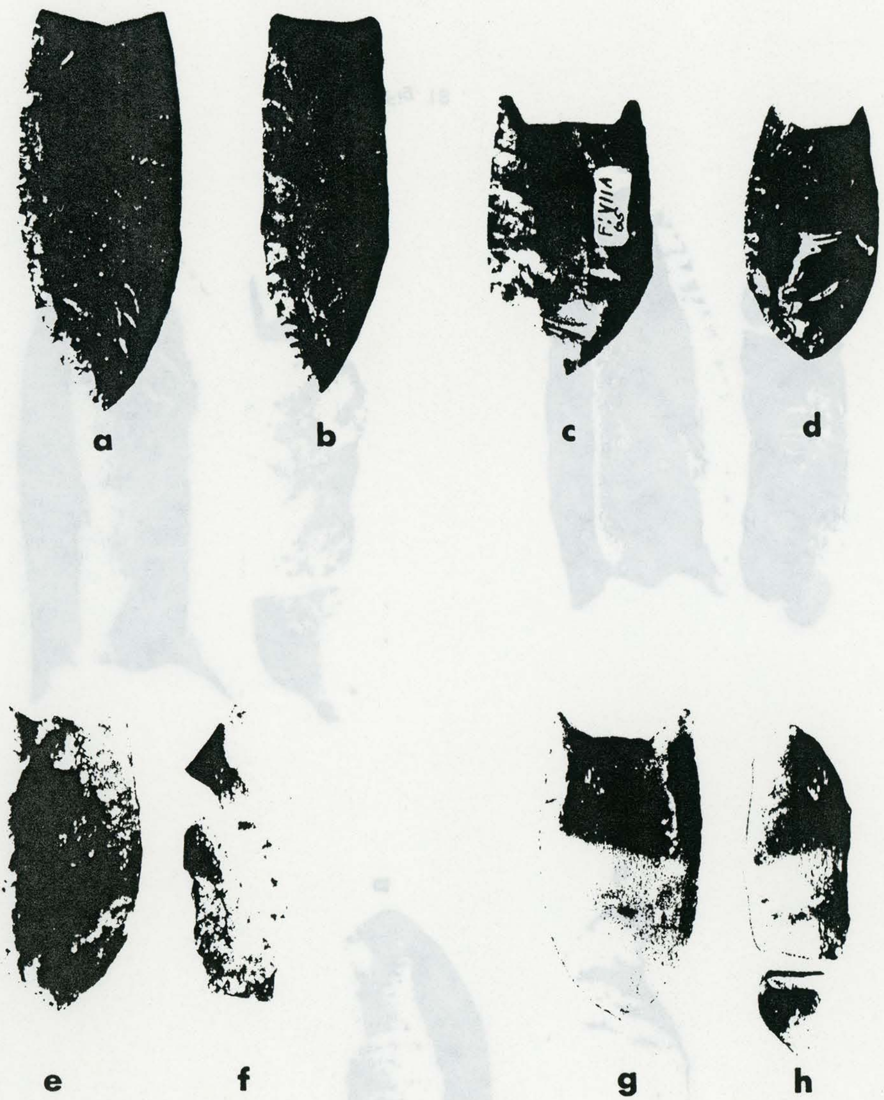


Fig. 20

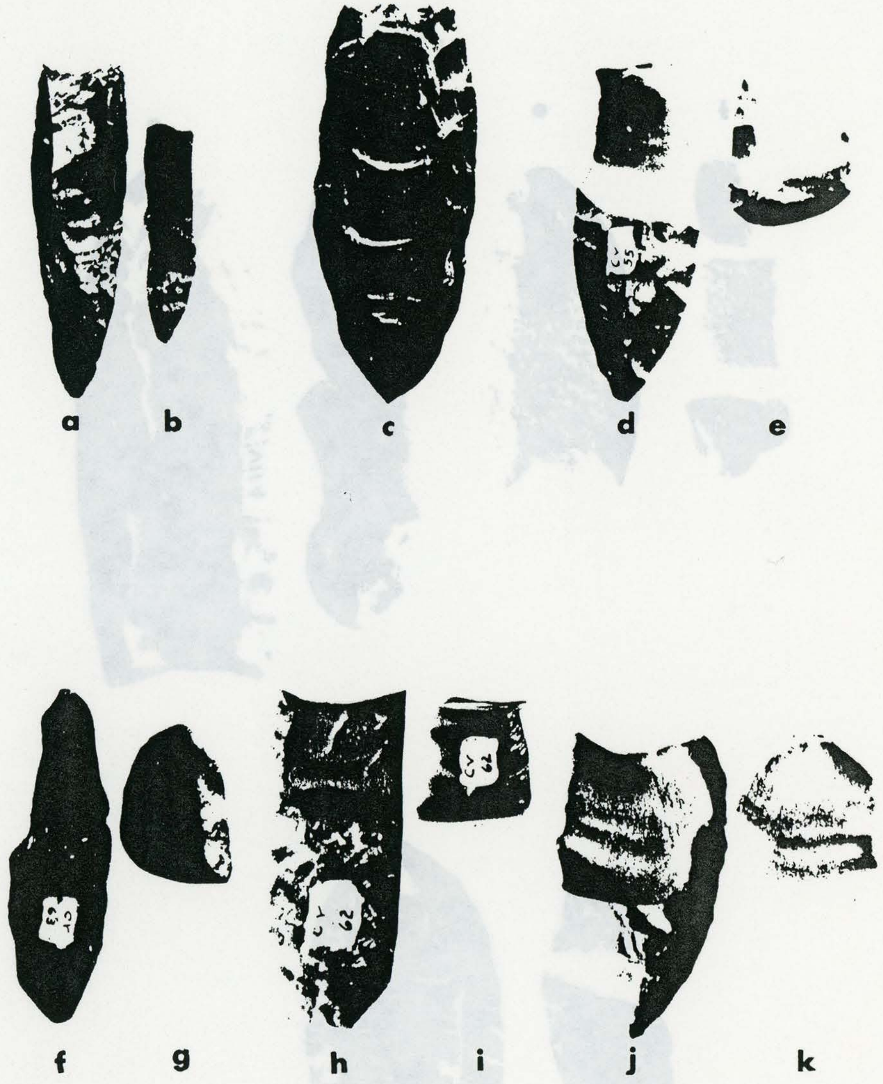
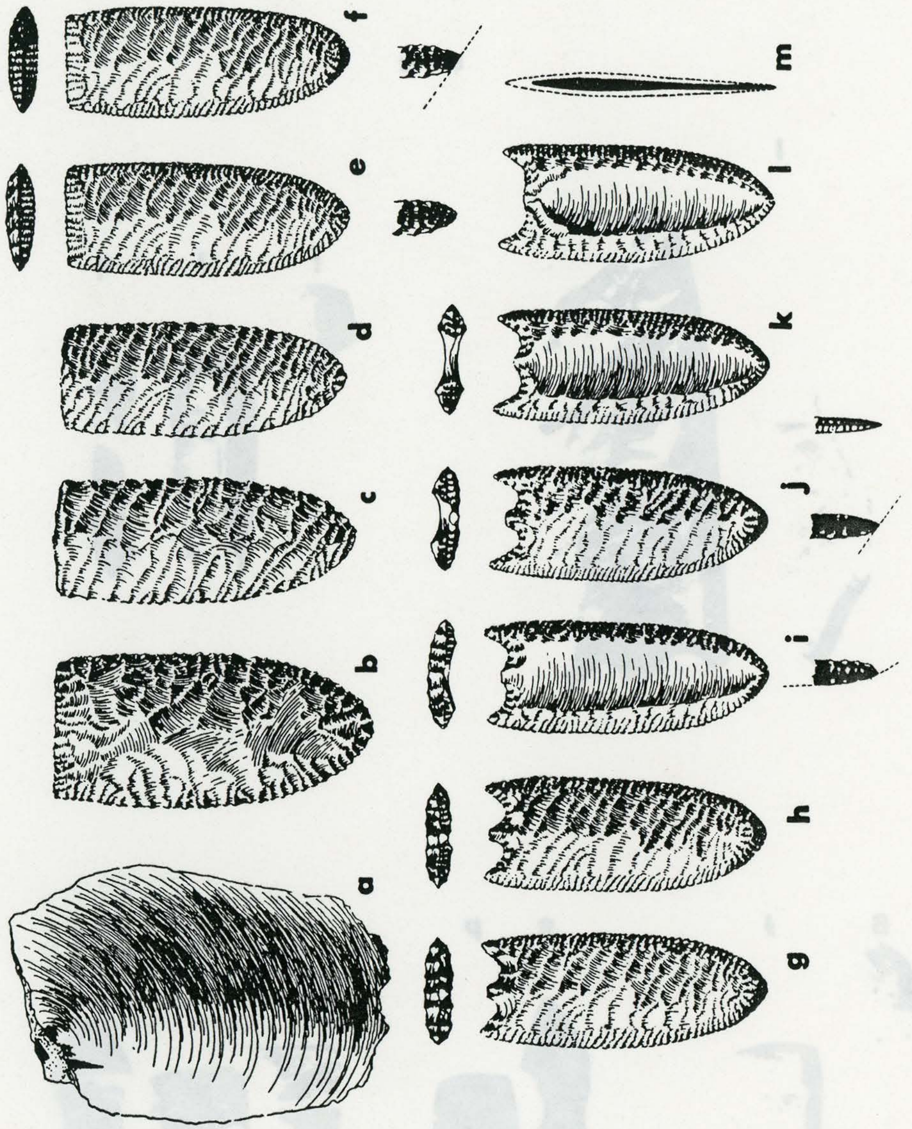


Fig. 21

Fig. 22

Fig. 23

Fig. 24



NOTES ON EXPERIMENTS IN FLINTKNAPPING: 3

THE FLINTKNAPPER'S RAW MATERIALS*

By Don E. Crabtree

A basic step in determining and interpreting working techniques of artifact manufacture is an understanding of the proper stone for toolmaking and reconciling the relationship of techniques to material. This is essential because the type of material used has a direct bearing on methods of manufacture; poor material restricting and fine material allowing the toolmaker to control the thickness, width, length and uniformity of the flakes. When one is able to control the four dimensions—thickness, width, length and curve—when removing a flake, he can then produce almost any tool he may need. Further, a working knowledge of the stone is essential to the knapper, as any variation in its quality requires a different method of flaking.

This text will attempt to describe and explain which materials are used in the toolmaking industry, to resolve what type of stone is adaptable for flaking and to clarify some of the working problems related to material which confront a flintknapper. My analysis of lithic materials is based on thirty years of experiments in stoneworking and may differ from the mineralogists's definition because our purpose is not the same.

What are lithic materials? Ideal lithic materials are kinds of stone with the necessary properties of texture, elasticity, and flexibility. They must be of an even texture and relatively free of flaws, cracks, inclusions, cleavage planes and grains in order to withstand the proper amount of shock and force necessary to detach a flake of a predetermined dimension. When the required amount of force is applied to a properly prepared platform, a cone is formed and, therefore, portions of the stone can be removed producing flakes with a very sharp cutting edge. There is a relationship to isotropism and conchoidal fracture, but the final results depend on the surface and the conformation of the material. The termination and shape of the flakes are controlled by the desires and ability of the person applying the force and, therefore, do not always resemble the shell-like or conchoidal fracture.

Synonomous names are sometimes used to describe the same material. For instance, slate is sometimes described as metamorphosed clay, metamorphosed sandstone called quartzite, silicified sandstone called quartzite, hornstone called flint, flint called chert, chert called flint, green jasper called bloodstone, etc. When speaking with other flintknappers, i.e., Dr. Francois Bordes, Dr. Jacques Tixier and Mr. Gene Titmus and we want to encompass the entire field of adaptable working minerals, we generally use the words "lithic materials", "flint-like materials", or simply "silex". The word silex has the advantage of unifying a single group of isotropic materials but the disadvantage of not indicating, by name, the differences of character, texture, color, etc. Therefore, we sometimes qualify these terms by describing sources such as "French flint", "Flintridge, Ohio flint", "Danish flint" "Oregon obsidian", "Idaho Ignimbrite", etc. This gives immediate identification of material and conjurs up a quick mental picture of the minerals and the problems or bonus qualities contained therein.

The stoneworkers first concern in choosing working material is quality of texture and this is governed by the fineness or coarseness of the microcrystalline structure of the material. Generally, the coarser the stone texture, the tougher and more difficult it is to remove regular and uniform flakes. But, conversely, the platform prepared on coarse material will collapse more readily than that fabricated on finer textured material. Certain materials will allow the platform to collapse, leaving a dull edge. Others haven't sufficient strength or flexibility to permit detaching a long thin flake and will break off short causing multiple hinge and step fractures. Personally, I cannot do the well-controlled pressure flaking on coarse-grained materials that I can achieve on finer, more closely-grained stone. The few collections I have had an opportunity to study have revealed this same relationship of well controlled flaking to fine-textured materials. Therefore, I reiterate that

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we must consider material in our analysis of tools, our explanation of type, and the study of technology.

Each source of stone has certain attributes of which the worker is aware. For example: when Dr. Francois Bordes and the writer were doing some experimental work at the University of California at Berkeley, materials for our project were from many and diverse locations, i.e., Southern France, Northern France, Indiana, California (2 locations), Oregon and Idaho, representing seven widely separated sources. After a week of working, the materials were almost entirely utilized and the resulting array of flakes were commingled in one big heap. Yet, if any single flake had been given us, and this happened, we could identify its origin without error. This serves to emphasize the fact that after the toolmaker has worked with a given material he will be able to identify its peculiar properties.

A toolmaker's criteria for identifying good lithic materials are: texture, luster, surface character, cortex (rind), color, transparency, sound, flexibility, sharpness of removed flakes and perhaps most important, the amount of resistance to the necessary force required for detaching a flake. The degree of luster is used as a guide by the tool maker to determine if the stone will permit him to regulate the amount of force necessary to remove a flake of a given dimension, and is one of the most useful attributes for determining workability. Variations of luster include glassy, waxy, greasy, satiny to dull, matt, flat, sugary, fine crystalline, medium crystalline, coarse crystalline and sandy.

Most types of suitable lithic materials have identifiable qualities recognized by the stoneworker. When choosing material, he will determine the homogeneity of the mass, appraise the texture and luster, and choose the raw material of appropriate size to produce the size and type of finished tool he desires. A myriad of bright colors is desirable, but color, in most instances, does not indicate workability of stone. When making an appraisal of the workability of flint-like materials, one may first tap the stone (lightly to prevent bruising) and listen to the sound of the tapping. If the stone gives off a dull sound, one can expect undetectable cracks, fissures and planes of weakness. If the stone has a sharp ring,however, the chances are good that the material will be of working quality. One may then remove a test flake, or cleave the stone to examine it further. If this shows the material to be free of crystal pockets, foreign deposits and shows the right luster, then the worker assumes the stone will lend itself well to the manufacture of an artifact. The final outcome, of course, will depend on the skill of the worker.

If the material is secured from pebble and cobble alluvial deposits, it may have lost a great deal of its identity due to pounding and rolling in the water. However, this rolling and pounding gives a clue to the workability of the stone. Thè projections and irregular edges receive the greatest portion of the impacts and each time the stone bumps against another cobble, a distinctive bruise is produced. Each of these bruises is actually a cone. The multitude of cones are super-imposed at random and intersect one another, reminiscent of the surface of the moon or to what we call "goose bumps". This type of surface enables one to identify which cobble has the desirable working properties. Cobbles lacking this type of surface can be assumed to be granular and unfit for the manufacture of stone artifacts.

Often reference is made to a large thick biface, irregularly surface-flaked on unsuitable material as "crude heavy biface", "crude percussion work", or "crude pressure work" whereas, in reality, the worker was a skilled craftsman to have produced any type of tool considering the poor quality of the stone. A stoneworker will always relate the quality of the workmanship to the material. Poor material showing skilled and controlled surface techniques definitely indicates good workmanship. Good quality material skillfully worked also denotes good workmanship. But we cannot reverse this procedure and assume that any artifact showing controlled work denotes good material. We must keep in mind the human factor of finding good work on both good and poor stone and poor work on both good and poor material. Also a factor in analysis is that some do not recognize thermally treated stone and may be viewing altered stone and calling it good material whereas it could actually be inferior stone improved by heat treatment. But when we see poor work on quality stone, I think, it is safe to assume that we are viewing unskilled work unless we find that the worker was merely preforming good material which was later to receive the refined techniques. We can relate techniques to material but we cannot relate material to techniques, and must be careful to judge character of material before we appraise the quality of the work.

II

VARIETIES OF LITHIC MATERIALS

(1) CRYSTALLINE VARIETIES OF SILICA

Rock Crystal
Quartzites
Sandstones, Conglomerates, Breccias
Bull Quartz
Novaculite

(2) CRYPTOCRYSTALLINE VARIETIES OF SILICA (Si O_2)

a) Chalcedony
Chalcedonic Rocks
Agate
Onyx
Sard
Sardonyx
Chrysoprase
Jasper
Bloodstone
Organic Replacements
  Casts
  Wood
  Bog
  Algae, etc.

b) Flint
Chert
Hornstone
Lydianstone
Touchstone

(3) NON-CRYSTALLINE VARIETIES OF SILICA (Silica Gels) (Si O_2) plus H_2O

Opal
Opalite
Silica Gels
Opalized Wood
Bog
Organic Replacements

(4) IGNEOUS ROCKS

Obsidian
Pitchstone
Ignimbrite
Basalt
Rhyolite
Andesite
Felsite
Tektite

(5) SILICIFIED SEDIMENTS

Welded Permeable Rocks
Silicified Sediments Shales and Clays
Siliceous Limestones

(6) METAMORPHOSED ROCK

Slates
Fine-grained Porphyritic Rocks
Metaquartzite

(7) EXOTICS

(8) EXPERIMENTAL MATERIALS

Glass
Porcelain
Ice
Resin
Starch
Anthracite Coal
Cold Tar
Gilsonite

Most solid non-fiberous materials such as bone, concrete, building stone, etc. have a semi-conical fracture.

INDIVIDUAL MINERALS

Following is a stoneworker's general classification and description of various lithic minerals, according to the above outline, useful, in different degrees, to the manufacture of stone tools.

The first four groups of the above mentioned outline are, by far, the most common used by both past and present stoneworkers. Igneous rocks are not a part of the quartz family, but, when available, played an important part as a source of material. Siliceous sediments and metamorphosed rock played a modest part as a source of material.

1. CRYSTALLINE SILICA

(a) **Quartz Crystal:** The use of this variety for making tools was rare. Sources containing crystals large enough to make tools of adequate size are uncommon. When quartz crystal is used in the manufacture of flaked tools, it must be treated differently from the cryptocrystalline varieties. Quartz crystal is formed in the hexagonal system around a seed crystal and, at times, the growth pattern of the crystal may be observed in what is called phantom quartz. The quality depends on the degree of homogenity, so the more tightly joined the growth planes, the better the material. Some varieties of crystal have a well-defined axis while others, like Brazilian pebble, show little or no growth patterns, having the character of glass. Most quartz crystals, however, do have flat planes of growth parallel to the sides of the crystal. In order to produce a good tool of quartz crystal, it must be oriented with an axis of the crystal, that is, the proposed artifact must be parallel to the flat side of one of the six sides of the crystal. When this is done, the applied force will move the flakes across the growth patterns thereby permitting more uniform flakes to be detached with the minimum of steps. If this procedure is followed, the result will be a thin, uniform artifact. When the artifact is made from a cross-section of the crystal, the resultant tool will have multiple step fractures because the growth patterns will not allow a long flake to be removed due to the intersection of so many cleavage planes of the growth pattern. The resulting artifact will be thick and ill-formed and no amount of skill can overcome the difficulties.

(b) **Quartzites and Silicified Sandstone:** From a stoneworker's point of view, there are at least two types of quartzites—the metamorphosed sandstone and the silicified sandstone. They are not readily detected and defined by eye, but when they are worked the difference is evident. They can both be percussion flaked, but there is a marked difference in their workability. The type of quartzite that has been cemented by chalcedony joining the granules of quartz together (silicified sandstone) allows more control of flaking than the metamorphosed variety. There is also a difference if the material is formed of angular sand instead of rounded sand grains. The brecciated silica cemented variety is the most desirable because it will allow long, thin, well-controlled flakes to be detached while the material composed of the rounded grans will not have as much elasticity. The brecciated and the rounded varieties respond readily to heat treatment if the matrix, or cementing medium, is chalcedony or a similar type of cryptocrystalline silica. The metamorphosed type of quartzite appears to have been formed by heat and pressure until it is vulcanized into a dense, compact mass with the bonding agent unidentifiable. This variety has little or no response to the thermal treatment. A laboratory analysis of the different types of quartzites would, perhaps, reveal much that would be useful in promoting a better understanding of this material so useful to the flaked tool industry. Metamorphosed sandstone has the quality of breaking to a very coarse granular edge which was of much value to the aboriginal. It is most useful for forming bone, wood and antler, but unsatisfactory for refined toolmaking. Flaking techniques are limited to percussion.

(c) **Sandstone and Conglomerates:** Metamorphosed sandstone has been discussed under the quartzites. Some types of sandstones can be useful for making thick, heavy tools when the percussion method is used, but most of the material is not suited for pressure flaking. The size and type of sand grains and the type of cementing material will have a direct relationship to the quality of tool produced. Since sandstone has so many variations, it is difficult to discuss them all. When one is making an appraisal of standstone, the first consideration is texture, which is determined by the size and kinds of sand particles and the joining of the grains whether by silica or calcium carbonate or other agency. A further appraisal would be the sonorous tone produced by striking the stone with a hammer. The final test, of course, is to apply the hammerstone. The most workable sandstone I have found is the quartzite or silicified sandstone from Hell Gap, Wyoming.

(d) **Conglomerates and Breccias:** Their workability will depend on what materials the breccias and gravels are composed of and the quality of their bonding agent. Both must be predominately quartz. If both breccias, gravels and bonding agent have the same degree of homogeneity and texture, then we have a material that is ideally suited for toolmaking.

(e) **Bull Quartz:** This type of silica is the pegmatite, or vein, variety usually found in colors of snow white, opaque and sometimes is colored by impurities. This type of quartz is one of the least desirable for making flaked tools, for the fracture is unreliable and the resulting tools are usually thick and ill-formed. Much skill is necessary to make even a very crude artifact from this material. The edges are usually dull and the surface covered with step-fractures.

(f) **Novaculite:** I have not had sufficient samples of novaculite to describe this material or fully appraise its properties. However, from my limited experience with this stone, I find it indistinguishable from many other materials used by the aboriginals. The samples I have are from Arkansas, but they may not be representative of the site. They are fairly coarse-

textured, being composed of microgranular quartz, and would fall in the category of good quality silicified sandstone. W. H. Holmes (1919:196-200) describes novaculite as being the same as cherts and chalcedonies with some having color.

2. CRYPTOCRYSTALLINE VARIETIES OF SILICA

(a) **Chalcedony:** Chalcedony is probably the purest form of the cryptocrystalline silica. In its pure form, it is transparent or semi-translucent resembling paraffin wax. Traces of foreign material and mineral salts may cause it to have tints of white-greyish, pale brown, dark brown, or black. The tendon color is the most common variety, however, it may also be yellow, amber, orange, red and sometimes it is even a delicate blue or purple. It is also found in other shades and these are given other names. Agate is a variegated chalcedony with the colors arranged in delicate concentric bands, frequently alternating with layers of opal. These bands often follow the irregular outline of the cavity in which the silica was deposited. This applies to banded, fortification, ribbon and other patterns found in agate. Some of the varieties of agate are eye, tube, tortise shell, mocha stone, scenic, moss, plume, iris, shadow, etc. "Rockhounds" have many sub-titles and many "ites" to identify the various forms of agate and chalcedony and are surprisingly well-informed about the sources of these minerals both foreign and domestic. If the stripes and layers of chalcedony are horizontal, it is then called onyx. Chrysoprase is a green chalcedony. Carnelian is the orange-red, or rust, variety. Sard is the brownish red; sardonyx is the same as sard, but has the alternating white bands.

Chalcedony is found in many and varied textures which relate to the fineness or coarseness of crystallization. The type with the finest micro-crystal structure has a waxy luster and, after heating, the luster is almost glassy. Possibly this variety contains more moisture for, when it is heat-treated, it requires more time and care during the heating and cooling off period. It has a tendancy to craze and crack easier than the coarser textured varieties. Of all the materials I have worked, this type of chalcedony has all the attributes desirable for stone flaking, particularly precision pressure flaking. After heat-treatment, this variety is often confused with opal by those who have never attempted stone pressure flaking. The banded varieties of chalcedony not as desirable because of the changes texture between the bands and layers. Ch cedony is the primary material or constitu in the formation of all the cryptocrystall quartz family rocks. When this form of sil infiltrates, fills voids, blends, infuses, is sorbed and combined with other minerals their salts, there results the wide range siliceous materials useful for making flak tools.

(b) **Jasper:** Jasper is the result of a co bination of chalcedony and argillaceous se ments or residual clays with a simultaneo absorption or infiltration of the two. Freque ly the clays will shrink and leave cracks whi will fill with chalcedony, giving the mater the appearance of being fractured. But, tually, the cracks are well-healed with chalcedony and a homogeneous mass created. This type of jasper is a good lith material and the chalcedony-filled cracks or add to the beauty of the artifact and do n impede the workability of the stone. Jasp which is green in color with red inclusions spots is normally thought of, and referred as bloodstone. Green jasper is opaque whi chrysoprase is semi-translucent. Actuall green jasper is only an impure form of chrys prase. Jasper may occur in various colors. Th iron salts in their different valences produ green, red and yellow material and, occasio ally, all are represented in the same sampl It would seem that the opaque or impure cha ecdony should be classed as a jasper regar less of color. The workability of jasper is th same as chalcedony, since this is based the amount of impurities and their textur Most varieties of jasper can be successful altered by the thermal treatment. I have foun only two exceptions: one is a coarse-graine greenish type of silicified clay from Tunis which was given to me by Dr. Jacques Tixie To the eye, this varved material appeared be no different from other similar types, ye when subjected to heat, there was no appa ent change in the texture or the workabili of the stone. However, we find that the ear people of Tunisia altered and worked this m terial very successfully.

Another unalterable example is an Idah material called "Bruneau Jasper" from th rhyolite at the bottom of Bruneau Canyon southern Idaho. This jasper is much desire as a gemstone because of its very distinctiv patterns and was also used by aboriginal man in that area. Early man was able to alter this stone, but, so far, I have had no success with thermal treatment of this material. Perhaps with further experiments and an analysis of the components, we may determine the differences between varieties of jasper. This material has now been successfully altered by Dr. Jacques Tixier by subjecting it to a high temperature heat over a prolonged heating period. It is apparent that past stoneworkers had a greater understanding of what constituted lithic materials and the longer I attempt to increase my knowledge of the lithic materials, the more respect I have for ancient man.

(c) **Organic Replacements:** Organic replacements are ordinarily composed of members of the cryptocrystalline silica family and have been much utilized for making flaked tool implements. Here, again, chalcedony plays the most important part as a replacement agent. In previous paragraphs, the variations of chalcedony are described. Chalcedony is, by far, the most common material deposited in voids left by the decomposition of organic substances and the dissolving of certain minerals. Casts are the total replacement of the original, without indicating the internal structure, and they will show the external form only. Replacements may preserve some of the internal structure. One of the most common replacements is wood but there are many others such as palm roots, aquatic plants, algae, bog material, shell and bone. These materials are usually quite distinctive because of the different species represented and can usually be identified by tracing their sources. When wood casts, replaced by chalcedony, are found in sedimentary rocks they appear to have finer microcrystals than those similarly replaced but found in lavas. This causes me to wonder if the sediments in which the wood is found may play a part in determining the crystallization that takes place.

(d) **Flint-like Materials:** Flint has a wide range of forms, textures, colors, and occurrences and there are those who usually consider any hard, tough stone to be flint and generally think of most arrowheads as being made of flint. It appears that there are three predominant forms of flint, the chalk flints, the limestone flints, and the lighter-colored forms, called chert. It seems to be a common practice in Europe not to differentiate between the silica forms but to group all cryptocrystalline forms of silica under the one name of "silex". For example, the toolmaker is commonly called a "flintknapper". For research and reading clarification, it would appear there is a need to distinguish between the many varieties of this material. This would better establish a relationship between the workability and character of a particular flint, as well as its geographic distribution. There are many paradoxical differences in flint that are not entirely understood even by the flintworker. Outwardly, or by visual inspection, one flint may appear to be exactly the same as another flint from a different site, yet, when subjected to the percussion method of detaching flakes, it does not work well, while for pressure work it will respond admirably. To cite an example: recent correspondence with Dr. Francois Bordes informed me that he had received a supply of flint from Sweden. To quote Dr. Bordes, "This is beautiful flint to make blades, works also fine by pressure, untreated, but it is very difficult to work by percussion. A most paradoxical flint!" he did not indicate if this material was freshly mined or surface, but he did say that he was going to subject this flint to the thermal treatment and see what results he would get after the heating.

To date, I can find little or no agreement among the prominent students of minerology on the differences or simularities of chert. The disagreement appears to be in the definition —some define chert as an impure flint, while others maintain that flint is an impure chert. Others argue that chert and flint are the same. Again, there are those who believe that chert is pre-Cambrian and flint is after the time of chalk formation. Some use as a criterion the different degrees of transparency or transluceny to determine which is flint and which is chert. Others use form as a standard, maintaining that flint forms in nodules and chert in seams or blanket veins. Some base their decision on color, declaring the dark colored material to be flint and the light colored to be chert. Even among stoneworkers there is disagreement, their criterion being the workablity, declaring flint will work better than chert, when, actually, it only represents a degree of quality. The homogeneity and texture of both flint and chert make them indistinguishable and there is both good and poor flint and good and poor chert. It is the degree of texture of flint or chert that determines the quality, workability and sharpness of the removed flakes. There has been much written about the behavior of freshly mined flint—sometimes called green flint—dehydrated flint and hydrous flint. It is common knowledge that when lumps of flint containing water are exposed to the elements they will be in no way as workable as freshly mined masses removed from below the frost level. Continued exposure to sun and frost will naturally create expansion and contraction and will, ultimately, form cracks, planes of weakness and internal stresses that are undetectable until one attempts to make a flaked tool. However, the smaller the pieces, the greater their ability to stand rapid changes of temperature. I find that the flakes detached by ancient man are as easily worked by pressure as the newly mined material. Of course, this factor may be pertinent to only certain types of flint and much material still remains to be tested. It is true that the more coarsely-textured flints will allow more expansion and contraction than the more finely-textured flints. For example: I have had a piece of Grand Pressigny flint which was collected in 1937 by Dr. H. C. Shetrone and given to me in 1940. I recently made this into blades and artifacts. I have had this material stored for these many years in an unheated building and yet, after 28 years of storage, it was still flawless. Recently Dr. Bordes and Dr. Tixier sent me some fresh material from this same locality. Comparison reveals no differencies in workability or character in the fresh samples and the Shetrone flint which was stored for some 28 years. I do not know how long it takes to dehydrate flint but I think that my stored flint indicates that dehydration is a long, slow process.

An additional test of the merits of hydrated or dehydrated flint is brought out in the alteration of flint by the thermal process (Crabtree and Butler 1964). I heat the flint to 450 degrees F. for at least twenty-four hours. After that length of time the flint should have been dehydrated. The purpose of heating the flint is not to remove the moisture, but to anneal the stone by changing its crystallinity, making the flint more workable and producing a sharper edge on tools. After flint has been slowly heated and cooled, it has a much glassier texture which increases the ease with which it is flaked whether by pressure or percussion. On the other hand, freshly mined saturated flint would have additional strength because the water filled void between the microcrystals would then transm the force from one microcrystal to the nex and prevent compression of the flint, thu dampening the force. Less force would then b required to detach a flake in freshly mine flint than in untreated, dehydrated flint. Thi peculiarity is more noticeable when one is detaching blades from a core by percussion.

High moisture content appears to reduc the brittleness and make the blades slightl more flexible. Personal conversation and correspondence with Dr. Jorgen Meldgaard of th National Museum in Copenhagen revealed some of the European thinking on freshl mined flint. Meldgaard has worked very closely with Andres Kreigh, a skilled flintworker from Jutland and, together, they wrote the book **"Mand Og Flint"** (p. 50-51) reciting their experiences and ideas on the stoneknapping techniques of Denmark. They conducted some tests with Danish flint under controlled laboratory conditions to determine the absorption of water by flint. These experiments proved the amount of water flint will absorb is considerable and Mr. Kreigh was of the opinion that freshly mined flint was more desirable and permitted more control than the surface variety.

To further illustrate the different varieties of flint: in one of our experiments at the University of California at Berkeley, Dr. Francois Bordes and the writer received some Harrison County Indiana flint given to us by Dr. Raymond S. Baby of the Ohio State Museum. This material had weathered out of limestone and was marked with rust streaks as a result of being hit by plow and field tools in the farm tilling. Yet, Bordes and I agree that it was one of the best flints in its natural state that we had ever worked, responding well to either pressure or percussion. We could see no reason to alter this material by using the thermal treatment. This flint must be of considerable age, as it had apparently laid on the surface since it weathered from the limestone of the area. This would, therefore, seem to substantiate my theory that one must consider the workability of each individual material separately, in addition to its mineral class. The many locations of flint and other materials each has its own character.

Those who have worked flint will agree that, in most cases, just under the cortex the flint is of a finer texture and is easier to work. When one appraises the formation of nodular flint, he will observe that the cortex is the surface of the nodule. If the cortex is insufficiently mineralized, or partly impregnated by the silica form of chalcedony, and is not a dehydrated flint, the cortex will be a combination of the silica and limestone, or silica and chalk. This will depend on the sediment in which the concretionary nodules of flint were formed. When a flint nodule is formed in a bed of limestone or chalk, the center will usually contain a fragment of fossil organic material. Around this organic matter, microcrystals of silica have formed concentrically if the silica charged waters continued to permeate the deposit of chalk or limestone. The growth of a pearl in a shellfish by the depositing of nacreous material on a piece of irritating substance is a suitable analogy. The development and growth of a nodule of flint has no divisions between the layers of siliceous material if it is of good quality. Often one may notice a change of color in the concentric deposits resulting from dfferent amounts of absorbed mineral salts, or a different mineral taken into solution by the silica charged waters. When several nodules are forming close to one another they may join. The joining of several will result in some interesting contortions that resemble some of our modern art forms and sculptures. The continued growth and joining of nodules can, ultimately, make a ledge or blanket vein of flint.

When experimenting with and examining the cryptocrystalline silica materials, I have noticed, on occasion, that the cortex is made up of common opal and under the common opal there is a change from the non-crystalline to the microcrystalline and between these two there is a combination of both. The texture of this portion of a nodule is semi-glassy with a greasy finish much prized by the stoneworker.

Good quality flint has most of the attributes necessary for the making of most flaked tool implements. The fracture of flint produces flakes with a sharp edge. This material has the quality of toughness which permits one to create a platform that will withstand the necessary pressure or percussion force without collapsing. This permits a wide thin flake to be detached without breaking off short in step-fractures. Flint has a resistance to "end shock". By "end shock" I mean when blades are removed from a core, the shock on the proximal end of the flake will be transmitted to the distal end of the flake, causing a rebound of the mass, resulting in a broken blade. This is one phase of elasticity.

There is considerable variation in the texture of flint, and the finer-textured varieties are the most desirable for flaking. The coarser-textured flints do not produce flakes with as sharp an edge as do the finer-textured flints. The edge of the flake can be only as sharp as the degree of microcrystal size. For example: a non-crystalline material, such as obsidian and opal, when cleaved or a flake removed, will break to the last molecule or to a theoretical infinity; while flint will break to the last microcrystal, producing an edge with a diminutive saw effect. A flesh wound made by the sharp edge of flint is slow to heal, as its coarse edge bruises and destroys the tissue cells, while obsidian and opal sever the cells and a rapid healing can be expected. Generally, the flint cut will heal leaving a scar, while opal and obsidian cuts will heal more rapidly and leave no scar.

In reviewing the many dictionaries, encyclopedias and publications with regard to materials, I find little or no information pertaining to qualities of flint. The best definition is probably that found in Dana's **Quartz Family Minerals** (1963). "Flint is nearly opaque with a dull luster and usually grey, smoky-brown, or brownish black. The exterior is often white from a mixture of limestone or chalk in which it was originally imbedded. It breaks with a conchoidal fracture, yielding a sharp cutting edge, and hence was easily chipped into arrowheads and hatchets." Dana also separates flint from chert by stating that chert is lighter in color than flint and that flint is in isolated nodules while chert is in beds. When the toolmaker removes all of the cortex and the color has been bleached and bleached by exposure and, possibly patinated, a problem has been created making it difficult to distinguish the difference between flint and chert. The material identification of a finished artifact is, indeed, a much more difficult problem than the identification of material at its source. It would appear that for the purpose of identification of lithic materials that limestone flint, chalk flint, chert, hornstone, Lydian stone and silex can be grouped as a unit for their qualities are primarily the same, yet, when the desire is to give a pinpoint description of a certain flint, a more definitive description should be given. For purposes of identification, present-day mineralogical terms should be used if their meaning is not synonomous and the mineral constituents are dissimilar. A breakdown of the individual flints that have individual characteristics could be useful in determining their aboriginal source and the trade and migration routes.

It may be well to combine chalcedonic rocks and flint in one main group, as flints are impure chalcedonies. They are both of the massive homogeneous cryptocrystalline varieties of quartz.

It has been known that under certain conditions certain forms of flint will patinate more readily than others. By examination of the materials in the formation of flints, one may be able to identify a difference in the elements contained in one that is lacking in the other. The amount of CO_2, carbon dioxide, or carbonic acid, H_2CO_3, in association with worked flakes or tools could also have a direct bearing on the rate at which the patina may be formed or the depth to which the patina will penetrate. One will note that the Lindenmeier Folsom material has little or no patination while worked surface material from other sites, of no apparent great age, is well patinated. Until a more exhaustive study is done on materials, no conclusions may be drawn, but this may prove a need for further experiments.

3. NON-CRYSTALLINE VARIETIES OF SILICA

(a) **Opal—Non-crystalline Amorphous Silica:** It is in this group that we have precious opal, common opal, opalite, diatomite and the various other amorphous replacements of organic materials. The chemical elements are a combination of silicon dioxide and water in variable amounts. Opal has a higher water content than the cryptocrystalline varieties of quartz, and has a hardness of between five and six on the Mohs scale of hardness and can usually be scratched with a knife. It is one of the few minerals that is non-crystalline and amorphous and is found frequently in botryoidal or stalactitic masses or as a replacement of wood or other organic material. It varies widely in color and appearance and has a resinous or waxy luster. The color of opal may be white, yellow, brown, red, green, blue, grey, black or any combination of the colors. Opal is the most brittle of all the silic minerals. Thin edges of opal can easily flaked by the pressure of the fingernail. Op with a rich display of colors is considered precious gemstone but, because of its rarit played little or no part in the toolmaking i dustry. It is safe to say, then, that when o sees an artifact made of this fire-quali variety that it may be considered a mode product.

Many types of opal are easily identifia due to their different physical properties a chemical constituents. Some of the varieti are: precious opal, that showing a brillia display of blazing colors; girasol, transluce and blueish-white; common opal and sem opal, that having many colors but without th fire-like reflections; cacholong, that which opaque and porcelain white; opal-agate, op of different color shades, sometimes bande jaspopal, opaque because of the iron salt and other impurities; wood opal, opal silic replacing the substance and structure of woo hyalite, a very pure form of opal associate with volcanic rocks and occurring in glass-lik concretions; fiorite, siliceous sinter; tripolit consisting of siliceous skeletons of diatoms. is not uncommon for opal to replace organ materials, the most common being wood, bo and other vegetable substances. Some of th opal replacements are remarkable becaus of the fidelity with which they replace ever cell and fiber of former materials even to suc an extent that the original species may determined. The replacements may, on oc casion, be of precious opal such as thos found in the Virgin Valley in northern Ne vada. However, it is the common opal, sem opal,jasper-opal and the agate-opal that ar the most common and also the most usef for making stone tools. The fossilized bog yield this type of opal in more massvie bed by replacing the stems, roots, seeds and leave of extinct flora. These beds are now found sedimentary deposits as blanket veins. Op replacements are common where volcanic as has rapidly covered the organic material.

Opal is not a particularly satisfactory m terial for making large flaked stone imple ments. Because of its high water content, is easily weathered; rapid temperatur changes and exposure will result in dehydr tion, causing the material to crack and craz The surface, upon drying, will resemble piece of glass that has been heated and suddenly chilled, causing a multitude of little intersecting incipient fissures and cracks, yet the piece will retain its form. However, upon tapping with a hammerstone, the opal will sound hollow or respond with a dull thud before it disintegrates. This character is distinctive only to opal and could well be used as a diagnositc feature in determining opal from chalcedony. This crazing and cracking makes surface opal almost invariably useless for flaking. However, opal freshly dug from below the frost line may be worked into small artifacts, if the work is done before the stone has a chance to dehydrate.

Opal is often confused with heat-treated cryptocrystalline varieties of quartz because the luster of the thermal-treated material very closely resembles that of opal. After the thermal treatment, cryptocrystalline varieties do resemble opal, but their hardness remains the same. Opal, of course, is a softer stone and a hardness test is one means of determining which is heat-treated material and which is opal. To avoid confusion when determining the kind of material, one can resort to a few simple tests to differentiate between opal and the heated cryptocrystalline materials of quartz. First, opal can be scratched by a knife. Second, opal is much lighter by weight or one can compare the specific gravity. Third, opal is unlike cryptocrystalline quartz in that it is more soluable in alkalies. For instance, one of the onyx varieties of chalcedony, or banded agate, may be immersed in an alkaline solution and the layers containing opal will be attacked and dissolved, leaving the layers of chalcedony unaffected. Because of its non-crystalline structure, a quality which opal and obsidian have in common, opal breaks to a very sharp edge. It is this quality that allows a flake to terminate to the last molecule thereby producing an edge with greater sharpness than that of any metal razor or any other variety of quartz. Because of this edge, a flake of opal can be very useful as a knife but due to its brittleness, it must be handled with a delicate touch. Obsidian is much more desirable as a lithic material because it is not as fragile as opal. In spite of its brittleness, opal is the most easily flaked of all materials, permitting very long minute flakes to be detached with a minimum of force. Its quality of elasticity allows the worker to guide the flakes with less effort than is exerted on most other materials. It is unfortunate that opal has the tendency to craze upon dehydration, for this limits the size of the artifact that can be produced from this material.

There appears to be a need for further research on the combinations of crystalline and non-crystalline varieties of silica. I have, on occasion, found materials that appear to be combinations of jasper and opal and others a combination of the varieties of chalcedony and opal. These combinations are well suited for toolmaking since they lack the high water content and, therefore, do not readily craze or crack and are not as brittle as the purer forms of opal.

4 IGNEOUS ROCKS

Some varieties of igneous rocks are useful for making flaked stone tools. The most desirable of this group are:

a. Obsidian, a volcanic glass of granite composition.

b. Pitchstone, an opaque grade of obsidian.

c. Ignimbrite, a welded volcanic tuff.

d. Basalt, a type of extrusive volcanic rock.

e. Rhyolite, a light-colored volcanic rock.

f. Andesite, a volcanic intermediate between basalt and rhyolite in composition.

g. Felsite, the name used for both rhyolite and andesite when a more accurate identification is impossible.

h. Tektites, a meteoric origin.

(a) **Obsidian:** A volcanic glass of granite composition, consisting of lime or potash and silicate with alumina and iron. It has a glassy appearance and is six in hardness on the Mohs scale. It is vitreous in nature with a conical fracture. The primary color is usually black, but it is sometimes red, brown, green and/or variously striped or mottled in a combination of these colors. The striping usually is a result of the flow structure of the obsidian. Some obsidian has the quality of iridescence, exhibiting rainbow colors and other varieties have the quality of chatoyancy, showing a gold and silver sheen. Both iridescent and chatoyant obsidians must be oriented to the proper axis to bring out this beauty of the sheen. The early people of Mesoamerica were aware of this sheen and seemed to prefer this quality for the manufacture of their polyhedral cores. Obsidian has all the desirable qualities and properties necessary for making flaked stone tools and it must have been a time of much rejoicing among the ancient toolmakers when a source of good obsidian was located. Today it is still thrilling to pay a visit to Glass Butte, Oregon and see the beauty of this material, for there is no monotony in the endless varieties of swirls, bands, colors, iridescence and chatoyancy and it is, indeed, a delight to work. It requires less force to detach a flake from obsidian than the cryptocrystalline quartzes and it works equally well for the percussion or pressure methods. Its only drawback is its limited strength. The cryptocrystalline quartzes are stronger and not as brittle as obsidian. However, the sharpness of the obsidian flakes more than compensates for the difference between the two materials.

The sources of obsidian are not as widely distributed as the chalcedonic rocks. Since it occurs in regions of vulcanism, it was widely used in the western United States, Mesoamerica, South America, Iceland and, to some extent, in the Mediterranean area and in Africa. It was employed in the manufacture of cutting implements, projectile points, utensils, mirrors, earplugs and ornamental pieces. There are multiple grades and kinds of obsidian relative to workability, character, and color and these differences can occur in the same zone of vulcanism. In the same volcano, different temperatures were reached which resulted in the production of different forms of volcanic glass. The high temperatures produced forms of crystobalite and tridymite, creating small spheres, or spherulites, within the material with a radiating or spoke-like structure and this is called snowflake obsidian. When obsidian contains these spherulites, the structure is weakened, making this material an inferior grade. A great deal of the obsidian in the Yellowstone Park area contains these spherulites, making it unsuitable working stone, as one must first delete these imperfections and, therefore, only small tools can be produced. There is also a difference in the texture of various obsidians from the same site. The coarser-textured varieties have less strength and, therefore, are not as desirable as the more vitreous types.

The age of the obsidian is also a factor in its workability: the older the obsidian, the more internal stresses and strains because the molecular structure is unbalanced by trying to assume a crystalline form, making the older material unpredictable for the manufacture of tools. This phenomena may be likened to old and new window glass; a glazier will sometimes refuse to cut old glass because of its brittleness. An example of this phenomenon in nature is evident in the obsidian found in perlite beds. Often it is so brittle from internal stresses that one cannot remove the surface by grinding on a lapidary wheel without almost exploding the obsidian. Much of the perlite is made up of the exfoliated obsidian. Areas producing this type of obsidian have the appearance of being an aboriginal workshop due to the exfoliated flakes. Some of the material will even resemble polyhedral cores due to the starch fractures caused by molecular internal pressures. However, this type of break is readily identifiable from those man-made, either by pressure or percussion. When I speak of old and new obsidian, I am making reference to the geological age and, at the present time, the age is only relative. Devitrification of obsidian is not a function of time alone since it may occur very soon after extrusion as a result of hydrothermal activitiy.

Gene Titmus, Henry Irwin and I did some toolmaking work at the Glass Butte and Burns sites and became aware of the additional amount of force required to detach a flake of similar size from a piece of Burns obsidian compared with the cobbles found at the Glass Butte site. When struck, the Burns obsidian has a resonance that is unnoticeable in the Glass Butte material. Until one is able to mentally calculate and compensate for the difference in toughness and homogeneity and allow for the difference in the force necessary to remove flakes of equal dimensions, it is difficult to change from the Burns material to the Glass Butte obsidian.

Some of the sites from which I have obtained obsidian for experimental purposes are the Island of Sacrifice near Vera Cruz, Mexico; Teotehuacan, Valley of Mexico; East of Magdelena, Mexico; San Blas, Mexico; Glass Butte, Oregon; Silver Lake, Oregon; northwestern Nevada; Fish Lake, Nevada; near Cederville, California; Coso Hot Springs near Little Lake, California; Glass Mountain northwest of Bishop, California; Clear Lake, California; Snowflake obsidian south of Salt Lake City, Utah; Iceland; the western slope of the Tetons, Idaho, Sweet, Idaho; and Owyhee County, Idaho.

Obsidian requires a different working technique than the cryptocrystalline varieties of quartz. When working obsidian, a softer hammerstone is used to prevent the shattering and collapse of the striking platform. It is also necessary to use more care in the preparation of the platforms to insure their withstanding the necessary pressure or percussion force. When working obsidian, the shock must be dampened with more care and the force must be directed toward the center of the mass more carefully. Also, the support is more critical and greater care must be exercised in holding the stone being worked. Because of the fragility of this material, a refinement of techniques is necessary when one changes from flint-like materials to obsidian.

(b) **Pitchstone:** A variety of obsidian with a coarser texture. The edges of the flakes are not as sharp, the platforms crush more readily than do those on obsidian and a little more force is required to remove a flake. I believe pitchstone has a slightly different water content than does obsidian, but, generally, the qualities are similar.

(c) **Ignimbrite:** A type of volcanic rock easily confused with obsidian. It is, however, a welded volcanic tuff and breccia. The tuff and breccia is produced by igneous activity originally by being discharged from volcanos in the form of ash made up of microglass-like particles with the same qualities as obsidian. The tuff from a single eruption may cover thousands of square miles and, under certain conditions, be altered until the glass-like particles are joined into one homogeneous mass. Upon close examination of a fractured surface, ignimbrite will exhibit numerous imperfections for, when the flake is being detached, it intersects the small granules of impurities which create unequal resistance to the force necessary to detach a flake, and these impurities leave a roughness on the flake. Ignimbrite is usually black but may be red, brown, blue or a combination of these colors usually in blended bands rather than mottled and there is sometimes evidence of brecciation. Ignimbrite is always opaque except when broken to a very thin edge which permits a little light to be transmitted and the thin edge will show tiny granules. The most accurate method of determining whether it is ignimbrite or obsidian is to examine a thin section under a microscope. Ignimbrite is commonly found in place as a ledge or blanket vein. When not in place, it is usually found in alluvial deposits as rounded cobbles which have a cratered surface caused by their being bruised against the other gravels that make up the alluvium. Since this bruising has set up planes of weakness on the exterior of the cobble, one must remove the outer surface before the cobbles can be worked.

When ignimbrite is used for making flaked stone tools, slightly different techniques must be used than those applied to obsidian. The edge strength is not as great as obsidian, so more care must be used in seating the pressure tool and a "stronger" platform created. Also, when using percussion to detach flakes, the impact must be farther in from the leading edge to prevent it from crushing or causing a step-fracture. When one becomes accustomed to this material, very fine narrow controlled precision flaking may be accomplished. Ignimbrite is quite plentiful in southern Idaho and was apparently a favorite material for early man in this area, for the greatest percent of the artifacts found here are made from this reconstituted tuff.

(d) **Basalt:** A form of extrusive dark grey, dark green, brown, or black lava, either compact or vesicular. The compact variety of basalt is the most suitable, depending on the degree of coarseness or fineness of crystallization of the material. Basalt has a quality of toughness and resistance to end shock, an important factor when the finished tool is to be subjected to rough usage. The more finely-textured basalts lend themselves well to pressure flaking. However, more force is required and a "stronger" platform is necessary to detach flakes than on obsidian and other vitreous types of material. By stronger I mean the platform must be made larger or be polished. When working basalt, a greater amount of control must be exercised to make pressure flakes of uniform dimensions because of the increased amount of pressure necessary to detach a flake and, at the same time, prevent the flake from collapsing. One may expect the flakes to be much shorter and to have more step-fractures than when working a finer-textured material. Pressure flaked artifacts of basalt may be expected to be thick, unnotched or slightly notched, stemmed or lanceolate and, in rare cases, precision flaked tools with sharp edges. Coarse-grained basalt can be most useful for certain types of tools such as those used to cut antler, bone or wood. The basalt tool is used in a saw-like manner.

(e) **Rhyolite:** A light colored form of lava basically of the same composition as granite, but cooled more rapidly. The more rapidly cooled, the more vitreous its nature. The more vitreous the rhyolite, the more suitable it is for making flaked implements. Sources of the finely-textured rhyolites are not particularly common and, because of this, they did not play an important part as a source of good material. When rhyolite is found with a minimum of phenocrysts, it can be a very satisfactory stone for the manufacture of flaked tools. The colors of rhyolite range from white to grey, pink, red and purple. The glassy rhyolites may be flaked by either percussion or pressure and well-controlled flakes may be detached. Fine quality rhyolite may be compared in degree of workability to good quality heat-treated jasper and chalcedony.

(f) **Andesites:** Andesites, because of their abundance and variety of color, texture and mineral composition are suitable for certain types of artifacts. They are, in general, darker than rhyolites and the dark grey color is common. They are transitional on the one hand into rhyolites, on the other into basalts. Their freshly broken edges are translucent when held in a bright light. Quartz phenocrysts do not occur in andesite which distinguishes it from rhyolite. Because of the wide range of constituents, textures and contained minerals, the degrees of workability are relative to the homogeneity and texture of the andesite.

(g) **Felsite:** It is difficult to discriminate between rhyolites and andesites that are devoid of phenocrysts, making it necessary to use an elastic, noncommittal name. For the light-colored rock of this class, i.e., those which are light to medium grey, light pink to dark red, pale yellow to brown, light green to dark green, dark brown or black, the term Felsite is convenient.

Rhyolite, andesite and felsite are almost as difficult to define as the difference between chert and flint. When these materials are made into artifacts, or found as flakes and discards, it is even more difficult to define the material than if the material's origin is known and its geological occurrence interpreted. To reiterate, the more finely textured, the more homogeneous the material, the more readily the material lends itself to being made into flaked implements. As a stoneworker, I can only attest to the fracture of these materials and the final analysis will have to be left to the mineralogists.

(h) **Tektites:** Glass-like material of possible extraterrestrial origin found and used aboriginally in Australia and India. Experiments were not done in this material because none was available.

5. SILICEOUS SEDIMENTARY

(a) **Welded Permeable rocks:** The impregnation of permeable rocks by silica (chalcedony) can alter a semi-porous material such as shales into a rock that can then be shaped into satisfactory tools either by pressure or percussion. This permeable group of rocks is indistinguishable from their unaltered counterparts except that all voids are filled and particles are welded into one homogeneous mass. Rocks thus formed may be altered by the thermal treatment and are well suited for making stone implements.

(b) **Silicified Sediments:** The introduction of, or the replacement by, silica into types of sediments such as clays, silt and sand particles in indefinite mixtures and proportions may both fill up pores or voids and replace existing minerals. These siliceous sediments include mudstone, claystone, siltstone, shale and argillite, and one may use still other names to distinguish the many different colors and textures. Material of this nature is usually found in ledges, blanket veins, in talus or in alluvial deposits. The siliceous sedimentary rocks are usually in tabular form often with varves and bedding planes. The sedimentary material having cleavage or bedding planes closer together than the thickness of the proposed artifact is undesirable because the flake will follow the line of least resistance. However, if the bedding planes are of approximately the same thickness as the desired tool much thinning may be eliminated. Thin slabs may be easily shaped into a variety of tools with a minimum of effort and a slight loss of material.

Silicified or opalized sediments can often be confused with metamorphosed sediments. The metamorphosed sediments are usually slate and shale with well-defined cleavage planes so closely spaced as to make the material unsuitable for flake implements.

When the texture is fine and the silicification is complete, this type of sedimentary rock is adequate for most flaked stone implements. It has been widely used and played an important part as a source of good material.

(c) **Siliceous Limestones:** Limestones containing variable amounts of silica lend themselves to the flaked tool industries in different degrees, depending on the amount of silica contained in the material. The calcium carbonate by itself is much too soft to result in a sharp cutting edge, but a combination of siliceous materials evenly distributed in the mass can make usable material. The greater the amount of silica—the more control one has in detaching flakes. The replacement by, or the introduction of, silica into limestone in indefinite proportions contributes to a wide array of textures, colors and mineral constituents. At the time of deposition, the limestone may have contained siliceous skeletons of diatoms, thereby increasing the silica content.

Limestone with a high silica content can be useful for making tools adaptable for rough use and when a sharp edge is not necessary. Siliceous limestone is very difficult to pressure flake and most of the forming of the tool must be done by percussion. The nature of this material is comparable to basalt in workability, texture and toughness.

6. METAMORPHOSED ROCK

Metamorphic rocks include all rocks which have formed in the solid state in response to pronounced changes in temperature, pressure and chemical environment which takes place, in general, below the surface of weathering and cementation. This process by which consolidated rocks are altered in composition, texture, or internal structure, by heat, pressure and new chemical substances are the principal causes of metamorphism—generally resulting in the development of new minerals. Minerals resulting from metamorphism are only useful if they have the qualities necessary to make flakes that may be controlled by pressure and percussion. Due to the normal coarse texture caused by the separation of the individual minerals, the metamorphics do not play a great part in stone toolmaking.

(a) **Slate:** Slate has been a fairly common material used for tools and ornaments but they are usually finished by grinding. However, the initial shaping can be accomplished by using percussion and pressure.

(b) **Fine-grained Porphyritic rocks:** The metamorphosed fine-grained porphyritic rocks have been used to some extent because of the lack of better material. Due to the intersecting planes of weakness, one can expect only ill-formed, thick tools with an irregular or dull edge.

7. EXOTICS

Exotic materials are those that do not readily fall into any of the foregoing categories. This class is merely to provide space for the unusual, the rare and those that need the assistance of a specialist in this type of mineralogy.

8. EXPERIMENTAL MATERIALS

(a) **Glass:** Glass is the ideal material for experimental work in the mechanics of fracture. Glass has isotrophic properties (having the same properties in all directions). Glass has much the same properties as obsidian and under the application of force, it responds in an identical manner. Both natural glass and manufactured glass are, by far, the best materials for studying fractures for they leave radial scars, fissures, undulations, step and hinge fractures, eraillures, flake overlaps, and the platforms and the bulbs of force well defined. Glass will reveal much more of the mechanics of force used in manufacture than will the more coarsely-textured materials. Man-made glass has a uniformity and even consistency greater than that found in natural materials and the imperfections are readily detectable. Of much importance to the experimenter is the fact that glass requires much less working force than the cryptocrystalline silicas. Even the aboriginal people chose glass as a preferred material, for glass tools have been found in some historic sites in the Americas. It was a favorite of the Australian aboriginies and a great number of the experiments done by Ishi were worked in glass.

Man-made glass is variable in flaking quality because of the different formulas, manufacturing methods and coloring compounds. When one becomes familiar with a certain kind of glass and continues to use the same quality, very satisfactory results may be obtained. If one cannot obtain the desired results when working with glass it would be useless to attempt to work with natural materials

Unless one is flintknapping continually, the hands will at first be tender. Practice will harden the muscles and form callouses.

Glass as an experimental material is easy to obtain in a variety of shapes, forms, colors and composition. An excellent source of supply in the archaeological sites of the future is the city dump. Here may be found cold cream jars, pyrex, jugs, broken plates and Bromo bottles and a particularly satisfactory item—old T. V. tubes. One should not delay too long, however, as our civilization is rapidly entering the age of plastics.

(b) **Porcelain:** For the study of fracture and comparison with the natural coarser textured stones, porcelain may be used as an experimental material for the fracture of porcelain is quite similar to some varieties of quartzite. However, it does not have the same toughness. Porcelain is also variable in quality suitable for flaking. That which has been fired at a high temperature is the best working material, such as discarded high voltage transmission line insulators and most porcelain bathroom fixtures. This material is very good for percussion practice work and better grades may even be pressure flaked.

(c) **Ice:** Ice can be useful for classroom demonstration of the fracturing of flint-like materials and protects the participants from injury from flying pieces of natural material.

(d) **Resin:** Resins may be used by students to practice pressure flaking, pressing off flakes and to simulate small cores, etc. for determining the nature of fracture.

(e) **Starch:** Starch has much the same character as resin and microblades may be removed with the tip of a lead pencil.

(f) **Anthracite coal, Cold tar and Gilsinite:** These are also materials that can be used to show the mechanics of fracture. This list is incomplete and there are perhaps many other substances and compounds that can be used for laboratory demonstrations to show how certain solids react to applied force.

The foregoing evaluation of the attributes of lithic materials may aid the experimenter and perhaps help the typologist. It is not the purpose of the writer to burden the profession with an analysis of every scrap, discard and flake, but only to point out some of the properties of lithic material that have significance to a stoneworker. This analysi is meant to create an interest in the Ston Age materials and to project some of th essentials of lithic material for toolmaking. I is hoped that an understanding of materia will create a new interest in the scraps o stone found in campsites and professiona digs. Perhaps flakes will have more meanin for the student other than just viewing then as a scrap of worked flint-like material an that, ultimately, these discards may someda help to complete the picture of the past.

III

A suggested list for appraising material follows:

1. **Material:** At the beginning of Part I is a list of various kinds of lithic materials including some seven groups and subclasses. This list is far from complete and includes only those materials with which I am familiar.
2. **Minerals:** Minerals are made up of many-ites and the complete list and breakdown will have to be left to the qualified mineralogists.
3. **Chemical Composition:** This represents the proportion, the arrangement of, and the relation to, the different elements and compounds involved in the materials useful for the flaked stone industry.
4. **Refractive Index:** This index is an accurate method of indicating the reflection and absorption of light in solids. The refractive index should be much the same in degree as texture, however, texture is only relative while the refractive index has a numerical value. Various minerals may have different light-absorbing values that would have no bearing on texture.
5. **Color:** Color is an excellent aid in the initial sorting of detritus, debitage, flake assemblages and accumulations of materal rejects discarded by people of the Stone Age. Certain distinctive colors do afford a key to the points of origin even though the textures do not always remain the same.
6. **Source:** The importance of material source has been previously discussed.

The character of external flakes and discards can contribute much information regarding the source (also see No. 15. Cortex)

7. **Geographical area:** The geographical area deals with the spatial distribution of material from known quarry sites and the transportation and trade routes of certain (special) materials. If the distribution is great, it would seem to indicate a material of special quality for the flaked tool industry.

8. **Geological Occurrence:** Geological occurence can be useful when the material is found in place. Certain attributes, types of crystallization, textures, colors and qualities may be a direct result of the geological nature in which it was formed. The finding in situ of a deposit of useable material will aid in a more accurate identification of material in question than will a flake found on the surface.

9. **Light Transmission:** Light transmission is an important identifying feature being useful in determining the colors by a transparency rather than a reflected light. If a thin flake is moistened, or a thick flake broken to a sharp edge, and then held toward a bright light, one can see the degree of translucency as well as the mineral structure. Wetting of the surface also serves to bring out the true color of the reflected light and, at the same time, aids in revealing the structure which may be characteristic of that particular material. In the field, it is often difficult to determine the difference between ignimbrite and obsidian. But, if the thin edge of a flake is held toward a bright light, the difference may be noted. Ignimbrite is generally opaque, or has a very uneven distribution of coloring matter in the form of granules, while obsidian has a uniform distribution of color with different degrees of translucency.

10. **Texture:** Texture is the most important key to the workability of lithic materials as it indicates the degree of crystallization. Textures range from the very glassy or vitreous to the more granular rocks. It can indicate: how much force is necessary to remove a flake; whether it can be flaked by pressure or percussion; the sharpness of the edges; and whether flakes of uniform dimension can be detached without the platforms or the flake collapsing. The finer the texture, the greater the control in making flakes, blades and tools.

11. **Edge Character:** The edge character of a flake can denote how useful the material would be as a cutting implement and also its degree of texture. The finer the texture, the sharper the flake. Tools made of the fine-textured materials are useful for cutting soft materials, such as leather, flesh, cordage, etc. Finer-textured materials are also ideal for pressure flaking and where a sharp edge is needed for knives, blades, and projectile points. For tools that will be subjected to rough usage, a material that has a coarse edge will be more satisfactory as it has more toughness. Coarse textured materials, such as quartzites and basalts, are excellent for designing a tool meant for forming and cutting bone, antler and wood. An illustration of the differences of a sharp edge and a coarse edge is the conversion of a cryptocrystalline quartz by the use of the thermal treatment. For example agate, in its natural state, has an irregular edge and this is the result of the size of the microcrystals. In its natural state, it has much toughness well suited for making tools which do **not** require the removal of long, regular flakes to produce an extremely sharp edge such as drills, perforators, scrapers, etc which are designed to withstand twisting, shock and general severe treatment. However, if a thin, well-formed knife with a razor edge is needed, one can be made from the same piece of agate if it is altered by heat-treatment from its original form to a material that has a very sharp cutting edge and is easily pressure flaked. The sharpness of the edge will indicate a fine texture while the rough edge will indicate a coarse textured material.

12. **Resistance to Shock:** This resistance is one of the qualities of stone that only the stoneworker of the past and a few present-day experimenters can fully appreciate. It is a paradoxical quality that is not entirely understood. The resistance to end shock is more noticeable in the technique of removing blades from a core, for one finds that certain materials can be compressed when struck by a hammerstone or a billet and will then expand without breaking the blade. Some materials do not have this resistance and, when a blow is delivered at the proximal end of the blade, there seems to be a transmission of force thereby causing breakage. At present, this resistance is confined to certain groups of materials and this is apparently due to the intertwining of the microcrystals of the cryptocrystalline group. The quality of toughness is directly associated with the resistance to shock and this quality prevents platforms which receive the impact of the blow from collapsing. Flint has this quality but it is not found in volcanic glass (obsidian). Of all the minerals I have worked with, nephrite jade has the greatest resistance to shock and is the toughest. Jade is not in the list of lithic materials because it is not one of the stones that can be flaked. It is mentioned only as a point of reference. Toughness is the quality of flexibility without brittleness or yielding to force without breaking.

13. **Elasticity:** This is the property or ability to return to its original form when the force is released. It is this quality that is related to end shock, the ability to recover without fracturing. Elasticity is included to avoid any possibility of confusing this meaning with flexibility.

14. **Flexibility:** This is a term meaning the quality to be bent, or pliancy or not being stiff or brittle. It is this quality that allows a person to control and guide a flake over a curved surface. If it were not for this property of flexibility, there would be no convex or double-convex artifacts. Different materials have different degrees of flexibility. Heated cryptocrystalline minerials and volcanic glasses have this flexibility to a greater extent than the coarser textured minerals. It is difficult for one not familiar with stone working to fully understand this property, but a flintknapper can control the flexing to an amazing degree.

15. **Cortex:** This is the exterior surface of the mass before it has been shaped into a tool. Most materials have a natural surface layer that is sometimes sufficiently distinctive to be useful for identifying places of origin.

Cortex (the natural or unflaked surface) is used to identify materials useful for toolmaking. Examples are: the partly silicified surface, or the incompletely mineralized exterior of nodules or masses of flint whether from chalk or limestone deposits; the bruised, abraded or naturally polished materials found in alluvium; glacial till or naturally transported deposits; surfaces retaining the impressions of cavities, voids, fissures, crevices and joints where silica-charged solutions may be deposited or the external surface impressions left by organic materials that have decomposed and their voids or casts replaced by siliceous materials.

16. **Homogeneity:** Denotes material in which the composition and the physical state are uniform throughout. Consisting of identical or closely similar material which may be a single substance or a mixture whose proportions and properties do not vary.

17. **Heat-treatment:** Whereby siliceous materials are subjected to the controlled thermal treatment and are, therefore, artificially altered, by man, to change their original structure to one that will lend itself more favorably to the production of certain stone implements. This process has been described in a previous article (Crabtree and Butler, 1964).

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NOTES ON EXPERIMENTS IN FLINTKNAPPING: 4

TOOLS USED FOR MAKING FLAKED STONE ARTIFACTS

By Don E. Crabtree

We cannot fully explore the flaking tools of the aboriginal without also including a consideration of the implements used to secure the raw material for the making of stone artifacts. The mining implements are most important, for they give a clue to the mining techniques.

The quarrying and mining of raw material for artifacts is an exacting and hazardous job, because much strength is needed to pry loose large blocks of stone and the worker is often struck by sharp flakes flying through the air. The stone must be removed in large enough blocks to produce artifacts of adequate size and must not be subjected to battering and bruising by indiscriminate pounding. Cracked, bruised, and weakened stone is not usable for the manufacture of artifacts and most quarries give mute evidence of poorly mined and rejected material.

Each source of raw material involves different sets of problems. The more massive the block of material desired, the more difficult it is to remove and also more difficult to protect from bruising. If the raw material were found on the surface, the problem of mining was eliminated. However, if the stone was found in situ, then an assemblage of tools had to be designed to mine it properly before it could be worked into useful artifacts. The quarrying, quartering, blanking and rudimentary preforming were done, generally, by the use of hammerstones. Wood, antler, bone or stone picks, wedges and scrapers could also be used to remove the overburden, expose cracks and fissures in the lithic material and lay bare any irregularities that could be used as striking or wedging platforms for mining with percussion tools.

I have done much quarrying for lithic material and have used sledges, mining bars, wedges, jacks, and abandoned aboriginal tools for the work. After several hours of strenuous labor, I succeeded only in removing one or two usable pieces of stone. This has convinced me of the tremendous amount of force and ingenuity necessary to detach large flakes or pieces of usable material for the making of artifacts. When mining, the worker must either strike toward himself, or sideways, so that he is often hit by flying flakes. Some of the large flakes quarried during prehistoric times were twelve to fourteen inches long, six to ten inches across and an inch and a half thick.

Removing flakes of this size requires a heavy, shock-resistant hammerstone. The mechanical problems involved in breaking over a hundred square inches (108-210 cu. inches) of flint-like material could not be overcome by just using a hand-held hammerstone. Three or four men may have worked together by attaching thongs to their weighty hammerstones.

DIRECT PERCUSSION

Percussion tools seen at quarries include ovate, discoidal, lenticular, cylindrical, spherical, conical, and biconical shapes. These tools are found in many sizes. Various hammerstone types are designed to fit certain phases in making artifacts or to suit certain types of mining operations. Their shape was governed by the manner in which they were held and the specific type of work they were to do. The ovate, spherical, conical or biconical tools were used to restrict the force of a blow to a confined area. A percussion tool with either a convex or pointed working surface will make a well-defined cone or a partial cone. The apex of the cone will be the same size as the area contacted by the percussor. The piece of material, called a flake, removed from either the core, or the artifact, will have, at its proximal end, a remnant of the cone. The flattened apex of the cone will indicate the area contacted by the hammer. A fine definition of the cone will indicate that a hard hammerstone was used. If the percussor is a soft hammer, it will contact more surface area and will conform with the surface being struck. This results in a diffused bulb of force.

Discoidal and lenticular types of percussion tools are used on both cores and artifacts for striking a confined area such as a prepared platform. They are held in a different manner and answer a different functional need. The stone is held between the thumb and fingers, as one holds a saucer edgewise. The striking surface of the hammerstone is around the entire perimeter and it is rotated to insure an even, uniform surface on the leading edge. Because force is concentrated in this way, the platform is prepared by abrasion, or grinding, so it will not be crushed by the force of the blow. Flakes removed by this type of tool will show a different character on the proximal ends than those removed by other types of tools.

It is common to find simple forms of scrapers at quarries and they are usually made on wide flakes of material obtained from the quarry. Their purpose may have been to remove soil from the overburden and to expose crevices and cracks to assist in the mining operation. Abrading stones are also found. These were used to remove the overhang from the top of the core face for platform preparation, but such stones are more commonly found some distance from the quarry. In such places it seems that the artifact was finished.

Stone hammers were the chief tool used to mine the flint-like material. Selection of a hammerstone was not accomplished by indiscriminately picking up the first cobble or rounded boulder that was available, as the broken and utilized percussion tools found in a quarry would lead one to believe. Percussion tools used for mining, or tool making, are usually of tough, granular stone which has good resistance to shock and abrasion. For mining, they range in size from three inches in diameter to as much as twelve and fourteen inches in diameter and they weighed from one and a half to as much as twenty or thirty pounds. For toolmaking, hammers vary from one to four inches in diameter. For blade making they are of various sizes; from the very small for microblade removal to the very large for detaching bigger blades. Hammerstone size is related to the dimensions of the flake being removed. Percussion tools are of both hard and soft stone, depending on what work is to be done. Selection must include size and material to suit each purpose. Normally, hammerstones are selected from waterworn boulders or cobbles. They are then used in their natural form, or slightly altered to fit the specific problem of the mining of the quarry or of fabricating the artifact, whichever the case may be. (Fig. 1 a-d).

Hard stones are normally those with a high silica content, such as agate, flint and chert nodules, chalcedonic rocks, and certain types of hard basalts and rhyolites, diorites, andesites, quartzites, and others of this general consistency. These are useful to induce great shock with a minimum amount of velocity. This is important when removing large flakes from the ground mass, and also for rough preforming.

The shock from the hammerstone to the artifact becomes critical when the area of the flake to be removed becomes greater than the cross-sectional area of the object, and some artifacts reveal only a part of the scar because of the overlap of subsequent flakes. Thinning of artifacts to this degree required a different technique other than those merely hand-held and struck with a hammerstone. Direct percussion with a hammerstone has certain limitations of accuracy and, even with soft hammerstones, the shock on the artifact is excessive. This shock factor may be partly overcome by the use of different types and sizes of percussion tools. The hafted hammerstone, or billet, affords a partial solution to this problem by allowing the speed of the percussor to be increased. Critical thinning requires a change in tools and methods. For excessive thinning, it is well to use a billet or to design a suitable hafting for the percussor and make a proper isolation of platforms. (Fig. 1 d-h).

Percussion tools made of softer stone, antler, horn, bone, ivory and wood, are useful for removing smaller flakes and blades and will not bruise the material. Agate hammerstones used on obsidian will cause shattering, collapse of platforms, induce unseen stresses and will render the material useless. A softer percussor will not have these ill effects. However, some hard hammerstones will become softened from repeated use until they have the same qualities as a soft hammerstone. Softening is caused by overlapping cones on the point or edge of the hammer.

It is important that the percussion tool be of a material other than one that has the vitreous qualities of flint, agate, chalcedony or those with a pronounced conchoidal fracture for, upon impact, they will project flakes toward the user causing cuts and injury. However, when no other material was available, hammerstones of flint-like materials were used. Flint-like hammerstones were usually discoidal and doubly convex, with the edges battered and rounded around the entire perimeter. The rounded edge gives a resistance to breakage not found in an angular piece. A hammerstone of flint-like material is much more difficult to control, for it causes excessive shock to the material being mined, or worked. It is almost impossible to avoid shattering of the artifact or raw material. A hammerstone of such material will break just as easily as the raw material or the artifact. If the hammerstone is hand-held, it may collapse and cause injury to the worker's hand. There are, however, areas such as portions of Utah, Northern Arizona and New Mexico where material for good hammerstones is limited because of the Permian sediments, and the aboriginal had to resort to the use of chalcedonic types of material for percussion tools. Sometimes aborigines in that area used dinosaur gastroliths.

Percussion hammerstones can be in a variety of shapes and sizes, but size and shape must be in relation to each mining operation, or with each technique in the stages of production of a stone tool. Hammerstones normally graduate in size from large to small as the flaking work progresses. Large, heavy hammerstones are necessary for the quarry work, smaller percussion tools being used as the artifact nears completion. Many artifacts were finished by the use of the hammerstone alone.

In addition to hard and soft hammerstones, percussion tools are of antler and other organic materials. Antler is carefully selected from prime antler of the caribou, moose, elk or large deer. Old, dehydrated, weathered antler is entirely too brittle to use as a tool. The bulbar end of the antler is the ideal portion to use for percussion work, since it is composed of both bone and antler with none of the soft spongy interior found in the balance of the antler. It has more weight and, therefore, imparts better balance to the billet. It is best taken fresh from the animal, as the shed antler loses much of its mass. The initial cut should be made close to the skull and then cut about ten to twelve inches from the burr. The extension of the antler provides the handle. The base and large parts of the antler are used for percussion work (Fig. 1 e-g) and the tines are excellent for pressur flaking (Fig 2b, 3a and f).

The amount of spongy bone in the interi of the antler varies with each animal an each species has antler of different qualit For example, the antler of caribou has thinner but tougher exterior than that of th elk, moose, or deer. The tough exterior of th caribou antler makes it ideal for use as a bill for percussion work, but some are undul light. When heavy percussion work is required, the bases of the antler are best. Th base of the moose antler is straight and som moose antlers are very heavy, enabling th worker to remove large blades from a core.

Percussion tools of antler and other organic materials may be used as the strike employing two different percussion techniques.

1. The worker holds the section of antler, or oth material in the hand in the same manner as on holds the unhafted hammerstone; i.e., held vertically by the fingers. Percussion tools held i this manner are used primarily for making blad or removing flakes from a core. These tools ar normally shorter and heavier than the billet. Th ends, not the sides or corners, are used.
2. Antler is used in the billet technique, i.e., th percussor is held at one end in the manner i which one holds a hammer handle.

When the antler is used in the same manner as a hammerstone, it eliminates the en shock to a degree not possible with a hammerstone, and a very forceful blow may be delivered without bruising the edge of the core There is also an absence of incipient cone when repeated blows are delivered to a cor by the antler billet and the flake scars ar more diffused than when using the hammerstone.

After good material has been secure either from the surface or by quarrying, th next step is to reduce the blocks or boulder into either core tools, flakes or blades. Thi was done by both the writer and prehistori man with the use of stone percussion tools My experiments incorporate the use of th anvil to support the rough lithic material. Th anvil is used when quartering the rough mas of material as well as when removing larg flakes and blades. The use of the anvil is no as the name would imply. One normally think of an anvil as an object on which metals ar pounded and shaped. In flintknapping, th anvil is used to support the material and pro vide inertia for the artifact. The blow must not be directed towards the face of the stone anvil and through the lithic material, for the blow will be opposed by the anvil and the opposing forces will either cause shattering or will induce strains in the material, rendering it worthless. The blow must be applied in such a manner that the force will be deflected away from the resistance of the anvil. This causes a shearing effect from the opposing forces, yet they are not in direct oppositon. The immobilization of the lithic material on the anvil allows the stone to be cleaved with the application of a minimum amount of force.

The shape and conformation of the anvil must suit each specific function, whether it be used as a simple support, or to strike against when using the block-on-block technique. When this technique is used, the anvil must be hard and resistant. Anvils can be of mediums other than stone. They may be of antler, bone, horn, wood and materials that are semi-yielding. Prehistoric people probably made use of anvils for quartering and for blade and flake removal. These are sometimes hard to recognize in the debitage, for they are usually of the same material as that found in the quarry.

By using a hammerstone, these blocks, nodules, or masses of material are then formed into blanks, later to be made into preforms and ultimately finished into artifacts. The hammerstone is used to pare all of the undesirable material such as cortex, inclusions, vugs (crystal pockets) and improper texture from the blank. The blank is now ovate or must be further reduced to the stage of a discoidal, thick and excessively heavy. It must be further reduced to the stage of a preform which can be transported to the place of occupation for the final finishing. The preform will be larger than the finished artifact but the general shape will be roughly the form of the completed tool. There is little evidence that all the stages of artifact manufacture were completed at the quarry site, for rarely is the quarry a suitable place for the time-consuming work of flintknapping. It appears that the aboriginal preferred to rough out blanks and preforms at the quarry and do his finishing under the more comfortable conditions of the campsite. There is some evidence, however, that large bifacial artifacts were made at the quarry.

Billets, rods, clubs, or hafted tools may be of soft stone, antler, wood, horn, shell, ivory or bone.

I first became aware of the use of billets in 1938 when, with the late Dr. R. A. Stirton, I was doing some paleontological reconnaissance work for the University of California. We were camped at a ranch which had been established in the early seventies in the vicinity of Walker Lake, Nevada. The elderly owner told of the Paiutes who had lived there when he was a boy. Any hard wood left unguarded would be taken by these Indians, and the spokes of the buggy wheels and tool handles would constantly disappear. The Indians told him that they used this hard wood in the making of stone knives. The rancher had never observed them making the stone knives, but he said they did use what he called "flint spikes" for their arrows. When we later found a deposit of obsidian in Northwestern Nevada, I was able to try the wooden billet technique. I applied the handle of my prospector's pick to the obsidian and was delighted with the results. Prior to this, I had always used the hand-held hammerstone as my percussion tool for roughing out a preform and then resorted to hand-held pressure for finishing. The wood billet worked very well as a tool for the intermediate thinning stage. Whereas the hammerstone made artifacts with well-defined bulbs of percussion, the wood billet allowed the removal of wide, thin flakes with a very diffused bulb of force. The billet struck flakes had much the same character as some of the prehistoric ones. This also led me to consider the technological patterns related to the tools used in the manufacture of artifacts. Since then, I have found very distinct flake types that may be related to both tools and technology.

INDIRECT PERCUSSION

The use of indirect percussion involves the use of an intermediate tool to receive the force of a percussion implement. This allows the force to be projected through the intermediate tool to the pre-established platform on the artifact. Indirect percussion allows the operator to keep the angle constant and to accurately place, with control and precision, the tip of the intermediate tool. This method allows and produces uniform flake removal. However, indirect percussion, does present the worker with the problem of holding the preformed material. For good results, two persons are required: one to hold the artifact and the other to hold the punch and strike. The intermediate tool may be composite, or of the same material. The punch may be of antler, horn, stone, wood, ivory or metal (Fig. 1 g, 2 b & c, 3 a). The percussor may be a rod, billet, club of wood, or hafted stone hammer (Fig. 1 d-h). The anvil or support must be of materials with sufficient resiliency to support the artifact without causing shock. If the material of the anvil is too hard it will crush the contact point of the artifact. Anvil, or support, may be of soft sandstone, wood, antler, or a pad of fiber, bark or hide may be placed between the artifact and the support to further dampen the shock. Indirect percussion may be accomplished with or without the use of the anvil, however, when the anvil is used, a flatter flake is produced.

Holding devices suffice as a poor substitute for a second person. Since holding devices were, no doubt, made of wood and lashings, no records remain except the information given by the early writers, Catlin, Sellers and Torquemada. There are many designs for clamps, vises and securing mediums and they are limited only by the individual's ingenuity (Fig. 2 a).

The use of the indirect percussion method by aborigines concerns the writer because of the apparent lack of evidence of the intermediate tools. My experiments convince me that this method is very useful in certain stages of the making of flaked stone artifacts. However, the only real evidence I have ever seen of prehistoric man's use of this method is the tools shown to me by Dr. Luther S. Cressman. These tools were made from sections of antler cut near the base of the skull at right angles to the long axis of the antler. These were about one and a half inches in length and were cylindrical in shape. The perimeter of one edge of the cylinder was placed on the lithic material and then struck by another implement. The scars also indicate that it was rotated to provide even wear on the surface end which contacted the artifact.

The indirect tool provides a larger surface area to receive the blow and, therefore, force can be delivered with greater intensity and more velocity, thereby producing flatter flakes. By flatter, I mean a flake with less curve. This technique also terminates the flakes at the distal end without margin, or what I call "feathering", without hinge or step-fractures.

The indirect tool has proven to be most useful for the removal of large blades from cores. One tool used for this method is a wooden chest crutch with a projection on the distal end which receives the blow. The chest crutch used by one person is a pressure tool, but if a second person strikes a projection on the crutch, it then becomes an intermediate tool. The tip of the crutch is placed on the core, or artifact, and the first person applies pressure with his chest to the proximal end of the crutch, while the second person simultaneously strikes the projection at the distal end of the end of the crutch. This method allows the worker to exert both downward and outward pressure, while the second person delivers a blow to the crutch with a billet, or percussion implement. This same type of crutch tool is used for making polyhedral cores, but pressure alone is used. The chest crutch has proven satisfactory for removing the channel, or fluting flakes in replicas of the Lindenmeier type Folsom point (Crabtree 1966, Fig. 13, p. 27). This type of tool is also used, and good results obtained, on large bifacial artifacts. However, two persons are required for this method, the first person to apply pressure to the crutch and the second person to reposition the artifact and hold it in the proper position after each flake removal. Should the applied pressure be insufficient to remove a flake, then the second person may assist by striking the projection at the distal end of the crutch.

If a second person is available, the artifact may be hand-held by the second person against two wooden pegs driven into a log. The second person may also hold the artifact edgewise against two stakes secured in the ground, sufficiently close to support the artifact, yet providing space for the pressure crutch or indirect percussion tool. When stakes are used, a piece of wood, or similar material, must be placed flat on the ground between the stakes to support the artifact and prevent it from being driven into the ground. Because this technique requires two persons and I have had no one available to help, there is still need for further experiments. When two persons are not available, then blades can be removed from a core by using this same method, but substituting for the second person, a suitable clamp or holding device.

The materials of the indirect percussion tool are very important for successful flaking. Tips must be of a material that will withstand the shock delivered by the percussion tool, for the tip of the tool has a tendency to collapse, or disintegrate, from repeated impact with the stone. The tip of the intermediate tool must be blunt to provide greater strength and to withstand the shock of sudden impact. The tines of deer and elk antler are useable as tips, but are short-lived for they must often be repointed as they become soft or split from use.

The use of stone for an intermediate tool has both advantages and disadvantages. The stone selected must be tough and be sufficiently hard to withstand the impact of the percussor. If the intermediate stone punch is used unhafted, its size leaves little space for placing and holding it on the artifact or core. The stone tool also creates more shock waves and a more pronounced bulb of force. Hafting of the intermediate stone tool aids in dampening the shock and prevents injury to the experimenter's hands.

The use of bone, either hafted or unhafted, for an intermediate tool has not proven very satisfactory, for it splinters and breaks when subjected to shock from the percussion implement.

The use of hard wood is unsatisfactory and does not lend itself to this particular technique for the wood will dissipate the force of the blow and it also splinters excessively.

Ivory is one of the best materials for making tips for the punch for it is resistant to splintering and breakage and it does not slip or soften as easily as antler.

Copper tips have proven to be one of the best materials for this type of experimenting. They, too, need to be resharpened often, as they become blunt in a short time, but they do retain their point longer than antler. The use of copper as a tool was probably limited to a small group of aborigines in the New World and did not play a large part in stoneworking.

PRESSURE TOOLS

Pressure tools are used to apply force to the perimeter of an artifact to detach, with accuracy and precision, flakes from the surface and, ultimately, design a functional tool. The percussion methods do not allow the degree of control and duplication of precision flakes that one can achieve with pressure. Pressure flaking permits the worker to control each individual flake, thereby producing an artifact that is regular in form, with a sharp cutting edge.

Pressure flaking implements used to alter stone from the rough to the finished artifact are made of many materials and are of numerous forms and various sizes (Fig. 2 b-d, 3 a, b, d, f-j). Size of tool varies depending on stages of fabrication of the artifact. Pressure tools may be made of antler, bone, ivory, fresh- or salt-water shell, hard wood, metal, seed pods (nut shell), teeth and parts of tooth enamel, stone (flakes, blades), pebbles, natural crystals, jade, and flaked stone pressure applicators. I suspect that what the flaking tool was made of was governed, to a certain extent, by what material was available, what type of work the tool was intended to accomplish, the type of material being worked, and what techniques were being used. The type of materials chosen and the design of the tool depended on what steps of manufacture the toolmaker intended to accomplish and on the planned design and size of the finished artifact.

The materials of which pressure tools are made are important: first, because of their availability; second, because of the choice of the individual or group preferences; third, because of the skill with which they were used; and fourth, because of the desirable qualities of the materials used for pressure tools. The material of the pressure tool is responsible, to a degree, for the technique and character of the completed artifact. Techniques used are pertinent to the material of the tool, for the different qualities of pressure tool material vary. Some lack strength and must be designed to overcome this weakness, resulting in a bit of greater dimension. Other pressure tool material has the ability to adhere to, and not slip on, the artifact. When slippage does occur, the platform must be redesigned to overcome the tool inadequacy and this results in a distinctive flake scar.

Antler is one of the best materials for making tools for pressure work. (Fig. 2 b, 3 a and f). Its only disadvantage is that the tip must be constantly sharpened to keep the point uniform. Antler is also variable in quality, depending on the genus and speices, the diet of the animal, the rate of growth, the calcium content, and on which part of the antler is used for the tool. It is important that the antler be free of natural oils and greases and it can be cleaned by soaking in wet wood ash. Degreased antler will provide traction between the tip of the pressure tool and the edge of the artifact. When using different mediums in my experiments, I find that antler, because of its hard structure resists abrasion, yet is soft enough to prevent crushing of edges. This allows the platform and the flake to be removed together, which leaves a razor-sharp edge on the artifact.

Bone pressure tools are usually more brittle than those of antler (Fig. 3 b, g-i). Bones from different mammals, birds, reptiles, and fish have variable qualities, depending on which part of the anatomy they represent. Ribs, if they are large enough, are preferable to the long bones but, unfortunately, these are not readily available and often one has to resort to the use of the limb bones (Fig. 3 h). Bone also must be degreased so it will provide more traction between the tip of the pressure tool and the material being flaked. A polished tip is undesirable. The more abraded the tip of the pressure tool becomes, the more firmly it may be seated on the platform without slipping. Bones with polished tips were not pressure flakers, but probably served as awls. Bone tools for certain pressure work can be made from the whole bones just as they are taken from the animal and they require only a slight amount of shaping. The splints, two on each side of the cannon bone of a horse, are solid and pointed. If the distal end is abraded slightly, a splint makes a good tool for light retouch (Fig 3 i). The penis bones of certain carnivores, such as wolf, bear, seal, etc. are even better than the splint of horses and similar mammals because they have a greater diameter and require little or no reshaping (Fig. 3g). The long bones of mammals should be cut lengthwise, either by scoring deeply and splitting, or by sawing. Cannon bones can sometimes be split by tapping a chisel along the backside of the bone. The bones of birds and fish are usually too brittle and light for any use except notching and for light pressure retouch.

Ivory constitutes the greater part of the tusks of certain mammals such as the elephant, walrus, hippopotamus, mammoth, and the narwhal. It has proven to be a very satisfactory medium for flaking flint-like material, but it, too, has many grades and qualities Ivory makes a very good pressure tool for it is fine grained, elastic, and withstands abrasion. It is stronger than bone and not as brittle. The best grade of ivory for pressure tools seems to be that from equatorial Africa. It seems to be more durable and have more elasticity than other ivory. Ivory resists shock and splintering better than either antler or bone. Walrus ivory is also very good, particularly that near the tips of the tusk. It is also interesting to note that mature adults provide the best ivory. Ivory from the hippopotamus is ideal for the tip of the chest crutch, such as that used for the removal of blades from the polyhedral cores. It appears to be harder than that of the elephant, mammoth or walrus, and it also resists slipping. Apparently this is due to a lack of natural oils.

The use of mammoth ivory for my stoneworking experiments has been limited to a single section of fossil ivory tusk from Siberia. It has proven satisfactory for pressure tools, but is considerably more brittle than that of the recent elephant. Possibly this is due to dehydration as well as a loss of oils. To date, I have not had an opportunity to experiment with the tusk of the Narwhal but feel it probably played little or no part in the stoneworking industries.

My favorite material for a tool is hard-drawn copper. It was also used to some extent by the Hopewellians (Shetrone, personal communication, 1940) and the Mesoamericans (Museo Nacional de Antropologia de Mexico, D. F. contains archaeological specimens which illustrate this). The limited supply may have prevented widespread use. There may be some opposition to the use of metal in experiments. However, my concern when experimenting has been to resolve the behavior of flint-like materials under percussion and pressure and the metal tip saves repeated sharpening and increases the number of experiments that can be done in an allotted time. Time and uniformity of tools are important factors in conducting experiments. Since the metal produces the same results as the antler tine, it is substituted merely as a time-saver. I have conducted sufficient experiments over the years using every conceivable tool material to prove the parallel results of each; and the mechanics of working the stone remain the same when substituting copper for the tip (Fig. 2 c and d, 3 d). Hard drawn copper has qualities not found in other metals. The degree of softness of copper closely resembles that of antler or ivory. This is important, for it allows the flinty material to be slightly imbedded in the copper so the tool will not slip. This permits the flaker to remove an edge without crushing, so that it remains sharp. When placed on a platform, the copper tip will let the worker apply both inward and downward pressure. In summary, copper pressure tools are easily sharpened, they resist slipping, and they have sufficient tensile strength for most experiments.

Soft iron and bronze are also satisfactory, but brass and aluminum, known to engravers as a dry metal, are much too slick. They are mentioned here only because I have tested them, but I doubt they were ever used by natives. Tools made of bronze, brass and aluminum have a tendency to slip. Iron may be used for pressure tools if it is soft or has been slightly annealed. Cast iron and steel are too hard to allow the stone to be imbedded in the tool. The result is slipping and crushing of the edge of the artifact.

Certain seed pods such as coconut, black walnut and possibly others of a hard durable shell can be used for pressure flaking. I prefer coconut shell among these materials. Its fiberous nature is different from that found in most wood. Hard wood is very useful as a percussion tool. However, when used for pressure work, it rapidly loses its shape and becomes splintered and soft. Ebony has proven the most satisfactory for pressure work, however, there may be many other woods of greater hardness and durability. When a wooden tool is used for pressure retouch, the tip of the tool must be placed well back from the edge of the artifact. This is done to provide a greater bearing surface on the wood, otherwise the stone will be imbedded deeply in the wood so that a flake will not be removed.

Shells of mollusks, both fresh and salt water varieties of bivalves and univalves, can be used for both percussion and pressure tools (Fig. 3 j). Shell has both the hardness and texture necessary for pressing off flakes. However, shell must be selected from the varieties that are of the correct shape and thickness. Composition of shell is variable and the denser varieties are better.

Teeth make a good pressure tool for retouching an artifact. The use of teeth gives much the same results as pressure work done with nutshell. Mammal teeth consist of dentine and enamel and, in some cases, ivory, as previously mentioned. The usable part of the tooth is the enamel. The teeth of most mammals are classified as incisors, canines, premolars and molars; but there is a vast difference in tooth structure and size among mammals. Incisors of some rodents may be used for pressure work, particularly for fine retouching, serrating and notching. The incisors of beaver, marmots, and other rodents are well suited for this kind of pressure tool. The canines of the many carnivores provide an array of sizes that may be used for assorted pressure tools. The sides of molars from the large varieties of ruminants are well suited for notching tools. But, because of their brittleness, tools made from teeth must be used with care and their use is limited to the removal of small flakes. One exception to this rule is the tooth of the sperm whale. This tooth seems to be midway between ivory and the enamel from a normal tooth and I prefer it over other teeth for flaking tools. Sperm whale teeth are not unduly brittle, they are large enough to form a variety of pressure tools, and they can be compared favorably to the qualities of antler and ivory.

Stone may be used as a pressure tool for applying pressure to the edge to resharpen an artifact. However, stone upon stone will slip and, therefore, it is difficult to use this as a tool and still control and duplicate flakes. The use of pebbles will result in a distinctive flake scar. Such scars are usually overlapping and of assorted dimensions. Jade is one of the toughest and most satisfactory to use as a pressure tool. However, it is expensive and not readily obtainable. My experimental tools of stone have been of jade, crystals of quartz and sapphire, flakes and blades of flint-like materials and a variety of pebbles of assorted composition. Pressure tools range from the very simple to the more comlpex. The simplest known tools would seem to be the pebble tools used in Australia and described by Norman Tindale (1965). He has observed the aborigines using their teeth to sharpen stone knives for use in the circumcision rites. As

mentioned above, I have found tooth enamel to be a satisfactory medium for pressure flaking and have often used the exterior plates of enamel as notching tools in the making of projectile points. Tindale refers to the use of pebbles for removing pressure flakes by hand-holding the pebble and rolling or pressing it on the edge of the artifact. I have tried this technique and have obtained satisfactory results.

The most complex pressure tools are probably those used by the Eskimo. They are made of ivory, antler and horn and have replaceable bits (Fig. 3 b). The bits serve a dual purpose, with one end for shaping and edging, the other for notching. Melgaard (personal communication, Nov. 1964) has found the bits, or pressure tips, to be made of iron, bronze, ivory and bone. Bone is most common, usually being the rib of the walrus. Rib bone is harder and more flexible than that of the long bones and, therefore, more satisfactory as a tool. The Eskimo designed a hand-held pressure tool which conformed to the worker's hand and provided sufficient hand surface contact to avoid unduly tiring the flaking hand.

Two other types of hand-held pressure tools from the Arctic are noted and described by George MacDonald of the National Museum of Canada (personal communication) "Those from the Western Arctic, around Norton Sound, are made in two pieces; they are elbow shaped and fit into the hand. They are very comfortable to use and allow much pressure to be exerted. They are made of a variety of material from wood to musk ox horn and bone. The flaking bit is invariably of ivory. I have not seen any of metal, but our samples are from a restricted area and time (ca 1886). The second type is from the Hudson Bay area collected in 1907-9. They are made of a single piece of caribou antler. They are generally larger than the Alaskan type and are held in a different manner. They also have cuts on the shaft to hold a pad of leather in place. Some are now missing this pad. The tips of these specimens are also grosser than on the Alaskan specimens and may have served slightly different purposes. It does not appear that fine retouching could be accomplished with them" (National Museum of Canada, Specimen numbers IV-C-511, IV-C-511a, IV-C-516, IV-C-516a, IV-E-204, IV-E-205, IV-E-206, IV-E-207).

MacDonald has observed the differences in construction and holding methods. I am sure that a study of artifacts produced by these tools would show differences in the methods of flake removal. Different type of pressure tools and different methods of holding will produce identifiable surface characterstics that may be traced in time and space.

Leather, hide, or skins are very useful in the stoneworking industries, for they provide a means of protecting the worker's hands. A protective material is most necessary for the left hand when one is doing hand-held pressure work. My favorite pad for the left hand is made from a piece of leather cut from the neck area of the Plains bison. It is thick, yet soft enough to conform to the palm of the hand. Leather is cut to fit the palm of the hand and a hole is provided for the thumb (Fig. 3c). I also use leather as a dampening agent to reduce shock to the artifact. Strips of hide are used to serve the handles of the pressure tools and rawhide and sinew are used to secure the tips to the handle (Fig. 3b). Pads of leather, or hide, are also useful for protecting the limbs for both percussion and pressure work.

SHOULDER CRUTCH

The shoulder crutch is used for pressure retouching and for the removal of small bladelets from cores. The crutch is of wood and designed with a cross piece to rest against the shoulder with staff about 14" to 18" long (Fig. 2d). A suitable pressure tip is attached to the distal end of this staff. The length may be variable, to suit the comfort and size of the individual worker. Use of the crutch allows the flaker to exert the greatest amount of pressure when hand holding an artifact. It enables the worker to take advantage of the leverage between the shoulders and the knees. This, in combination with using the muscles of the legs and thighs in opposition to the back and shoulders, creates many times the amount of force that can be obtained with a simple hand-held pressure tool. This method allows the amount of applied force to exceed the weight of the worker. To measure the amount of force, I have placed a small bathroom scale between my knees and put the tip of the crutch on the scales and the crosspiece of the crutch against my chest or shoulder. I was able to exert a force of 300 pounds, yet I weigh only 165. This tool is most useful for retouching large bifacial artifacts by means of pressure alone.

ABRADING TOOLS

The uses of abrading and grinding materials are endless. They are used to sharpen the tips of the pressure tool and for grinding the edges of artifacts for platform preparation. The bonding of the abrasive, the fineness or coarseness of the grains and their hardness make them suitable for this purpose.

Material for abrading tools can be of any substance with loosely adhering grains of sand or of volcanic tuff. The substance must be soft enough to allow the grains to loosen as the abrasive becomes dulled. This prevents the pores of the abrasive material from clogging and glazing. This is most important when grinding antler, bone, ivory, or tooth enamel.

When the pressure tool is being ground and sharpened, it is pushed, pulled, and rotated across the abrading stone, preferably a loosely cemented sandstone or volcanic tuff. This type of sharpening results in groves being worn in the abrasive stone from repeated use (Fig. 3e). Sometimes these functional scars are erroneously called arrowshaft smoothers; however, from grinding, the base of the grooves is usually semi-concave or an inverted boat shape, whereas, arrowshaft smoothing scars are parallel the entire length of the abrading stone.

Abrading tools used for platform preparation may be of a much harder material, as flint-like material does not clog the pores of the abrading stone, but only dulls the abrasive grains. As the grains become dulled, a new fresh area may be used.

After repeated use of the abrading tool, multiple parallel cross-hatching lines, or slight grooves, will appear on the surface of the tool. Sometimes they will resemble an overlap of lines such as those we are familiar with in the game "tic, tac, toe". These scars result from exposing new abrasive surfaces on the whetstone.

LEVER

The use of a lever as a pressure tool received scant mention from early observers (e.g., Catlin, Sellers and Torquemada) of aboriginal flintworkers. Yet, the use of levers and fulcrums must have played some part in the stoneworking industries. Since the materials from which the levers were made were not of the quality to withstand fire, or the ravages of time, there is much lack of evidence of their use. I find the use of the lever to be most important in resolving the mechanical behavior of flint-like materials. I have used this device primarily on cores to interpret the amount of force and the relationship of the downward and outward pressures for removal of blades under controlled conditions. A detailed account of my results with this device will be given in another place.

WEARING OF TOOLS

There are definite holding patterns of pressure or percussion tools which are characteristic of each technique. The manner of holding when striking or pressing will result in the contact portion of the tool becoming abraded from continued use. This contact surface portion of the tool can be diagnostic in determining the manner in which the tool was held and gives a clue to which technique was used.

The pointed (conical or bi-conical) ends of the hammerstone permit the worker to strike in a restricted area. A tool of this shape and with its identifiable scars is generally used for the removal of blades by percussion. A hammerstone with a flatter, or semi-convex surface, is generally used to remove wide flakes with a diffused bulb of percussion. The diffusion of the bulb will depend, largely, on the amount of surface contacted by the hammerstone. Should the hammerstone be used for thinning and striking as on the edge of a bifacial artifact, facets will develop on the tool from wear, for as one edge becomes worn, the hammerstone must be turned to expose new striking surfaces of the tool. Blows delivered by the hammerstone for thinning purposes are struck in a different manner than those delivered for blade or wide flake removal. Flattening of the tip of the pressure tool denotes a straight downward thrust characteristic of removing blades by pressure.

Pressure tools used for retouching an artifact will show the edge striated and abraded from the center of the tip toward the base and the tip of this tool will tend to sharpen itself from repeated use. When the pressure

tool is pressed downward on the edge of an artifact, the tool develops facets and it must be repeatedly sharpened. Hand-held pressure tools used for trimming flakes or turning edges will show scratches and erosion of the sides of the pressure implement. The micro-grooves on the tip of the pressure tool will be approximately at a right angle to the long axis of the tool.

The tip of the notching pressure tool is not used, for it lacks sufficient strength to remove the material from the notch. The thin edge of the notching tool is placed against the edge of the artifact in such a manner that the tip of the tool extends above the artifact and pressure is exerted to either notch or serrate. Continued use of the notching tool will erode a concave area in the edge of the pressure tool. When the tool becomes too worn to serve any further use, the opposite edge can then be used. As the working edge of the tool becomes worn, the tip of the tool will resemble an hourglass or will have a strangled appearance.

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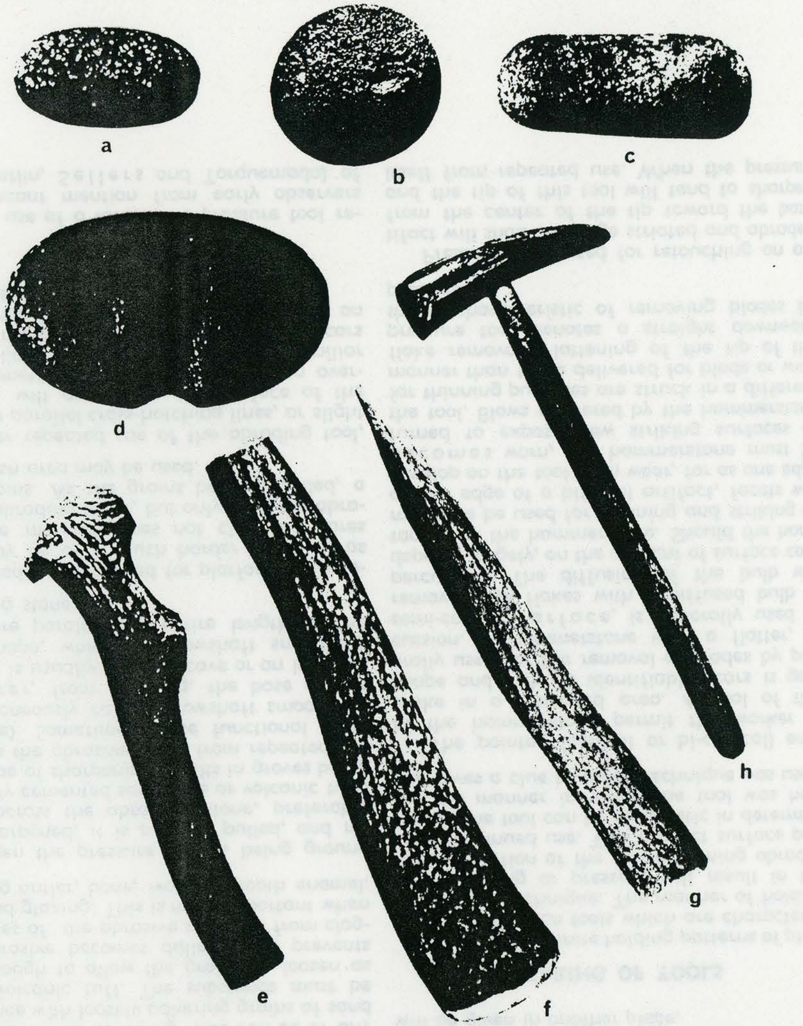

Fig. 1 Percussion tools: **a,** andesite hammerstone, a hard hammer for preforming and blade removal; **b,** hammerstone of vesicular basalt, a soft hammer for preforming and blade removal; **c,** sandstone hammerstone, a soft hammer for working glassy materials; **d,** a medium hard basalt hammerstone modified for hafting and used for quarrying and splitting large cobbles; **e-f,** antler billets used for percussion flaking, **e,** 25.5 cm. long; **f,** 28.5 cm. long; **g,** section of elk antler, 27.5 cm. long, which may be used either as a billet for percussion work or as a punch for indirect percussion; **h,** hafted hammer, 30 cm. long, with a head of water-buffalo horn which may be used for direct or indirect percussion.

Fig. 2 **a,** clamp used for holding cores when removing flakes and blades by indirect percus sion or pressure; **b,** wood haft with an antler tip, 38.1 cm. long; **c,** wood haft with a cop per tip, 29.5 cm. long, both **b** and **c** may be used as pressure tools or as punches fo indirect percussion, **d,** short crutch with crosspiece and copper tip, 40.2 cm. long, use for pressure retouching or for removing blades by pressure.

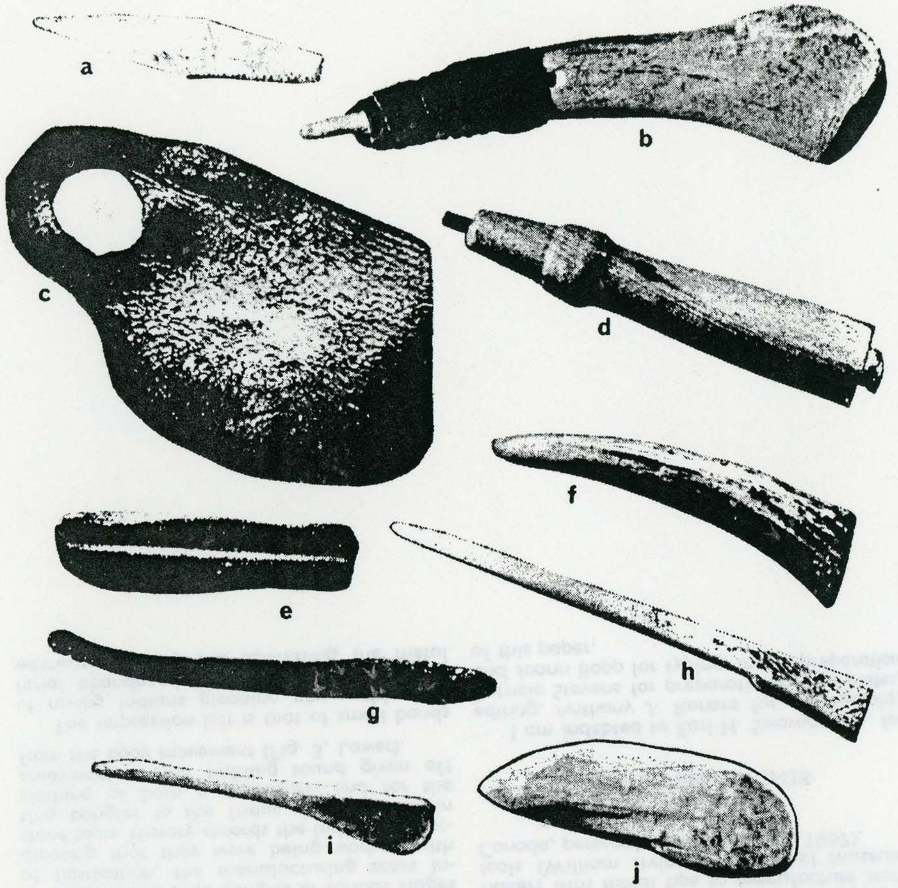

Fig. 3 Pressure tools: **a,** elk antler insert, 9.5 cm. long, may be hafted or used as is for pressure or indirect percussion; **b,** Arctic style pressure tool, slotted antler with bone insert, 19.4 cm. long; **c,** leather pad for hand protection when doing certain types of pressure flaking, 17.3 cm. long; **d,** awl handle with copper tip, 15.5 cm. long; **e,** an abrading stone used to prepare tips of pressure tools; **f,** elk antler tine, 12.2 cm. long; **g,** a baculum used as a pressure tool, 14.8 cm. long; **h,** pressure tool made with a piece of long bone, 16.3 cm. long; **i,** splint bone used as a pressure tool, 11.1 cm. long; **j,** pressure tool made of heavy marine shell, 10.2 cm. long.

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ARCHAEOLOGICAL EVIDENCE OF ACCULTURATION ALONG THE OREGON TRAIL

By Don E. Crabtree

About one hundred fifty feet above the Snake River in South Central Idaho, near the present Upper Salmon Falls Power Plant, is one of the camp grounds of the Oregon Trail pioneers (Fig. 1). Debris found at this site gives mute evidence of both the hardship of the pioneers and the ingenuity of the Indians. Today, our maps dismiss this place of history with the terse legal description of Township 8 South, Range 13 East, Section 3, East Boise Meridian.

Here the immigrants were faced with a long and difficult climb to the top of the canyon and this spot, with its abundance of water and fish, was an ideal place to rest the animals and members of the wagon train party before hazarding the sinuous grade. The type and amount of debris found at the site indicate that the stay was brief, but long enough to repair the harness, wagons, water barrels, and make the loads shipshape before continuing the journey. The Indians were keen observers and must have watched closely the activities of these interlopers. Masters in the art of making and using stone tools, they must have watched with fascination the white man wielding the coveted steel knife, working and straightening the metal of the wagon wheels and doing other metal work.

I first visited the locality about thirty years ago at the suggestion of Daddy Vader, a Hagerman pioneer, who told of seeing the flats near Owsley's Crossing covered with teepees, racks of salmon drying in the warm sun and the inhabitants busy catching fish and doing their many chores. I studied the flaking debitage at the Indian campsite, which has since been destroyed by road construction, and then went to the nearby campground percussor. However, one metal point bears of the Oregon Trail parties. Over the years it had been eroded by the prevailing west winds and many pieces of scrap iron, broken glass, wornout harness parts, flakes of flint-like material, stone anvils, four completed metal points, one broken aboriginally made metal knife, bangles, and other metal artifacts in various stages of manufacture had been uncovered.

The iron objects are of special interest because they offer archaeological evidence of culture contact and change along the Oregon Trail a century ago. The irregularity and character of the scars on the scraps of iron indicate that stone tools were used in the manufacturing process. Two anvil stones with functional battering scars and several bruised and broken hammerstones were found. No stone chisel was found at the site, but battered pieces of tough, siliceous stone were comingled with the metal debris and pieces of scrap material bore highly irregular coarse cuts indicating that the chisel was stone rather than metal. Scars on the metal are rough and concave, indicating the use of a stone hammer. The size and depth of the scars indicate that the iron was first softened by heating and then a stone anvil and hammerstone used to pound the metal to the desired thinness or thickness. Heating made the metal easier to work. Some of the pieces were probably parts of barrel hoops, or thin strapping, and would need no thinning but could be formed into arrowpoints by merely using a stone chisel and a suitable scars which are smooth and cleancut, similar to those left by the common cold chisel, indicating that a metal chisel may have been used to form the stem.

Several of the metal artifacts were abandoned during various stages of manufacture for reasons that are not clear. The random character of the scars on many of the iron objects suggest unfamiliarity with the raw material. A few of the unfinished pieces seem very close to completion by modern standards. Time and patience may have run out or existing stone tools may have been used for just one more time.

Other metal artifacts found at the site that were apparently worked with stone tools were: (1) a broken knife-like object with a long tang (6.1 cm) probably designed to be inserted into a handle, (2) a piece of metal

(14.2 cm), discarded before completion, was apparently being thinned by a process of heating and drawing with the worker using an anvil stone and hammerstone (Fig. 3, Upper), (3) a small punch-like object (4.3 cm) formed by pounding the lateral margins.

Four completed projectile points were found, each with variable form and outline: One (5.5 cm) has a concave tip, probably the result of use, another (3.5 cm long) has the stem broken off; and the remaining two are unbroken (Fig. 2). One of the finished points was made from a piece of laminated metal and then rubbed or ground for final shaping and forming.

Also found were bangles in various stages of fabrication, the manufacturing scars indicating that they were being worked with stone tools. History records the Indian as knotting bangles to the fringe of his buckskin clothing as both a decoration and for the enjoyment of the tinkling sound given off from the body movement (Fig. 3, Lower).

The impression left is that of small bands of roving Indians gleaning any usable material abandoned by the pioneers on their westward journey and converting the metal into points and cutting implements for the Indian. Acculturation is the process recorded here as Indians changed from stone to metal as a working medium. For the Indian, the metal point was a convenience because the same point could be recovered, straightened and reused and ready-made metal points were soon to be available in quantity as a trade item. The change was probably very rapid since no living Indian informant in Idaho recalls the manufacture of flaked stone tools. We may guess that this site on the Oregon Trail marks the beginning of the end of native flintknapping about A. D. 1850. In Point Barrow, Alaska, Eskimos modified the process of change by fashioning ivory flakers with metal tips to manufacture stone tools (William Irving, National Museum, Canada, personal communication, 1967).

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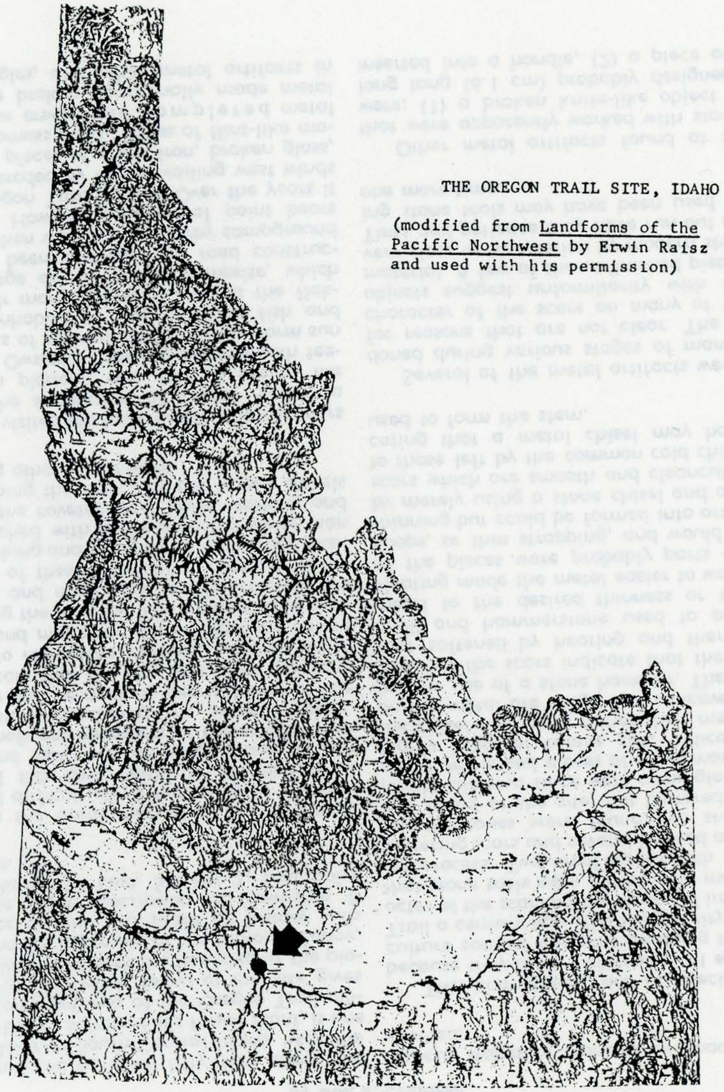

THE OREGON TRAIL SITE, IDAHO
(modified from Landforms of the Pacific Northwest by Erwin Raisz and used with his permission)

Fig. 1: Map of Idaho showing the location of the Oregon Trail Site.

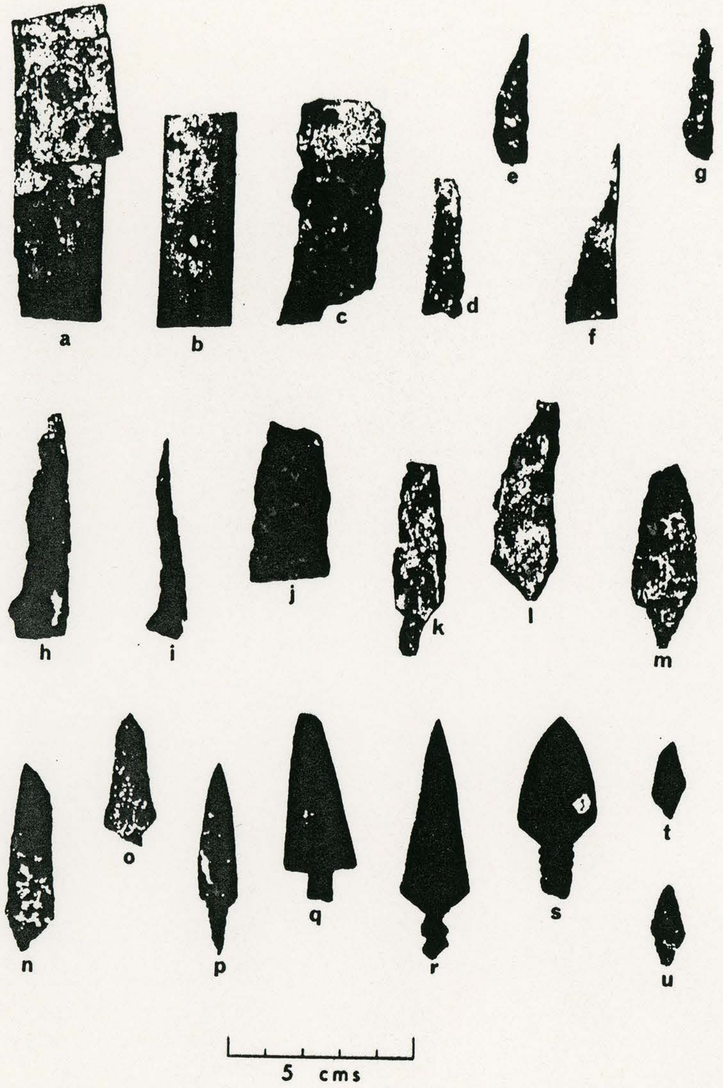

Fig. 2: Sequence of manufacture of metal points and used specimens from the Oregon Trail Site.

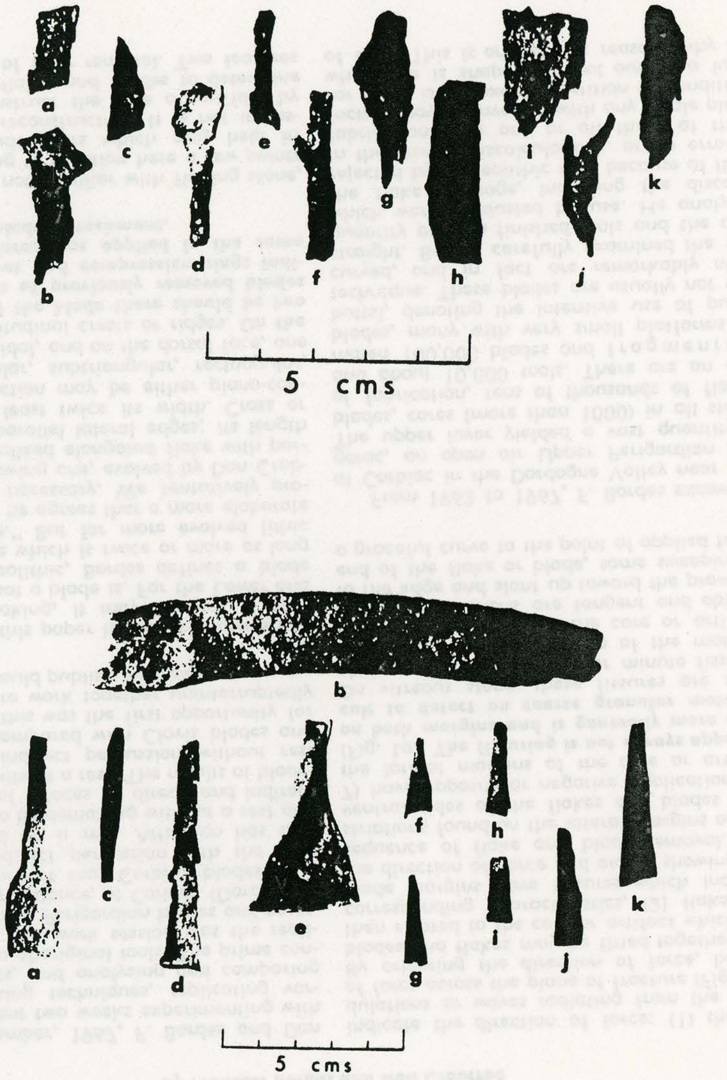

Fig. 3: **Upper,** assorted metal objects probably worked by stone tools; **Lower,** developmental sequence of metal tinklers or bangles from he Oregon Trail Site.

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THE CORBIAC BLADE TECHNIQUE AND OTHER EXPERIMENTS

By Francois Bordes and Don Crabtree

In September, 1967, F. Bordes and Don Crabtree spent two weeks experimenting with several flaking techniques, replicating various artifacts, and analysing and comparing their work to aboriginal tools. The prime concern during this work session was the replicating of Upper Perigordian blades and cores, as found, for instance, at Corbiac (Dordogne). Bordes thought that Corbiac blades were made by indirect percussion with the core being placed on a rest. Attention has also been given to blademaking without a rest and to thinning of bifaces by direct, and indirect percussion without a rest. The results of blademaking by indirect percussion without rest have been compared with Clovis blades and cores. Since this was the first opportunity for the authors to work together uninterruptedly we felt we should publish our findings.

Because this paper is primarily concerned with blademaking, it may be well to consider here what a blade is. For the Lower and Middle Palaeolithic, Bordes defines a blade as "any flake which is twice or more as long as it is wide." But for more evolved lithic assemblages, he agrees that a more elaborate definition is necessary. We tentatively propose the following one, evolved by Don Crabtree: A specialized elongated flake with parallel to sub-parallel lateral edges; its length equal to at least twice its width. Cross or transverse section may be either plano-convex, triangular, subtriangular, rectangular, often trapezoidal, and on the dorsal face, one or more longitudinal crests or ridges. **On the dorsal side of the blade there should be two or more scars of previously removed blades with force lines and compression rings indicating that force was applied in the same direction as blade detachment.**

For those not familiar with flaking stone, it seems fitting to mention here a few points regarding blade scars which may help in analysis and reconstruction. It is not impossible to reconstruct the core or artifact by reassembling flakes and blades to determine the sequence of their removal. Two features indicate the direction of force: (1) the undulations or waves radiating from the point of force across the plane of fracture (Fig. 1a). By orienting the direction of force, broken blades and flakes may be fitted together and then related to the core or artifact which has corresponding characteristics, (2) flake and blade margins have fissures which indicate the direction of force and aid in showing the sequence of flake and blade removal. The striations found on the lateral margins on the ventral sides of the flakes and blades (Fig. 7) have opposite or negative duplications on the lateral margins of the core or artifact (Fig. 1a). **The fissuring is not always apparent on both margins and is generally more difficult to detect on coarse granular material.** On vitreous stone, these fissures are more obvious. These striations, or minute fissures, are due to the compression of the material as it is removed from the core or artifact. Marginal striations are tangent and oblique to the edge and slant up toward the proximal end of the flake or blade, some sweeping in a graceful curve to the point of applied force.

From 1962 to 1967, F. Bordes excavated at Corbiac in the Dordogne Valley near Bergerac, an open air Upper Perigordian site. The upper layer yielded a vast quantity of blades, cores (more than 1000) in all stages of fabrication, tens of thousands of flakes, and about 10,000 tools. There are an estimated 100,000 blades and fragments of blades, many with very small platforms (or butts), denoting the intensive use of punch technique. These blades are usually not very curved, and in fact are remarkably often straight. Bordes carefully examined the vast quantity of both finished tools and the ones which were exhausted by use. He analyzed the flake debitage, including the discards rejected by Palaeolithic man because of flaws in the stone, miscalculations, or an error in fabrication. Any one or all three of these factors may be involved with any single piece, for there is no exact repetition of conditions when one is shaping a tool out of a lump of flint. This is one of the reasons why unfinished or broken tools and debitage are important for understanding material culture. They must be collected and studied because they provide us with an insight into the normal stages of development of the tools. This will prevent errors in interpretation such as confusing the preparation of the edge of the core platform with traces of use as a pushplane.

Bordes eliminated both pressure and direct percussion as the main blademaking technique at Corbiac, and defined the manufacturing method as indirect percussion with rest. He then did a number of experiments, eliminating various other manufacturing methods to resolve the blade and core technique used at Corbiac and by the Perigordians and other Upper Palaeolithic people. This took much time and work, for each experiment had to include the many individual stages of manufacture. Ultimately he was successful in consistently reproducing the cores and blades of this type.

Unlike other artifacts which have definite shape, outline, and functional purpose, cores are quite variable. Their forms, styles, and types are many, and the technological patterns vary, each retaining multiple diagnostic traits. Because the core demands frequent reshaping for blade detachment, it is reduced in size and even changed in form and character from the first to the last blade removed. Then the exhausted or malformed core is either abandoned, or further modified into another artifact. The core may be simply reduced to usable flakes with sharp cutting edges. End products such as these would hardly be recognizable as former cores. A large population of either malformed or otherwise abandoned cores usually indicates an abundance of raw material.

At Corbiac the numerous cores can be roughly divided into five categories (other kinds of cores do not concern us here) which are: unidirectional, bidirectional, globular, mousteroid, unclassifiable, and fragments (this fragmentation is the consequence either of breakage during work, or more often, frost action in the ground. The unidirectional cores (Fig. 1a and c) have a single striking platform; the bidirectional two, usually opposed. Among the unidirectional cores, the pyramidal or conical type (flaked all around, see Fig. 1c) seems conspicuously absent. The cores always show either cortex or preparation scars on one side. The bidirectional cores present several subtypes.

Preparation of prehistoric cores at Corbiac:

The Corbiac core was usually shaped out of ellipsoidal nodules of banded flint, which abound in the immediate neighborhood, and may be as large as a foot or two across. Usually smaller nodules were used, but these big nodules were also broken into fragments or flaked into huge flakes and cores made out of these large flakes. A bifacial ridge was then flaked along one edge to guide the first blade. Occassionally two or three ridges were produced to guide the first blade. The striking platform was made sometimes before, sometimes after, this ridge preparation and almost always at an acute angle with the side of the core. These are sometimes huge cores, up to 23 centimeters long, but some must have been even bigger, since in Corbiac blades have been found up to 26 centimeters long. In the neighboring site of Rabier, J. Guichard has found foot long blades. Some broken blades from either of these two sites must have been even longer.

The unidirectional cores are more or less prismatic, although often one side is unworked or shows only the preparation scars. The bidirectional cores show interesting variations and subtypes. The first variation is very much like the unidirectional cores, except that there are two striking platforms, one at each end and blades were taken either alternately from one or the other end, or a series from first from one end, then from the other. These we call **opposed.** Sometimes the cores were shaped in such a way that they presented about at their middle an obtuse angle (Fig. 1d). In that case, the blades unable to take a sharp turn, terminated at the middle of the core and were flat. This is probably linked to the need of the Perigordians to to have straight flat blades for the Gravette projectile points. This type can be called **opposed angular.** A variation which does not play an important role is the **opposite rectangular,** in which the angle is more or less 90°. Then there is the **opposite alternate** type, in which the blades were taken on each side of the

core from the two striking platforms (Fig. 1b).

Experimental work:

Our duplications of the Corbiac cores during Bordes stay in Idaho were mainly unidirectional but a few were bidirectional. The Idaho specimens were almost entirely made from either cobbles or ovoid lumps of obsidian with outside measurements of from seven to fourteen inches before preforming. After the top of the cobble was removed to provide a striking platform, the overall length averaged between six and ten inches.

The following is a description of our experiments of replicating Corbiac blades and cores by indirect percussion with rest.

Preforming the core:

Invariably the preforming of the core is the most difficult and important step in blade making, and the "Corbiac technique" is no exception. At Corbiac a number of what would appear to modern man as perfectly good preformed cores were abandoned by Palaeolithic men who knew better. If the core is not properly made there will be failures: the blades will fail to detach, they will step or hinge fracture, platforms will crush, the end of the core will be taken away by the blade, blades will vary too much in thickness or width, will terminate short, bulb of force will be accentuated, shatter lines and fissures will be present, the blades will have prominent eraillure scars, compression rings and undulations, or will break into fragments or split in the middle. We cannot emphasize too strongly the importance of core preparation (Fig. 2). It is impossible, or at least almost impossible, to remove true blades from an improperly prepared core and no amount of skill can overcome poor preparation or conquer certain strains and flaws in the material.

A suitable piece of material, relatively free of flaws, of adequate size and proper texture is selected for the experiment (Fig. 3a). The size of the rough material selected will depend on just how large a blade is desired and of course on what is available. Since our experiments were done at Crabtree's home in Idaho, we used mainly obsidian for it is plentiful here and we had very little flint. We would have preferred to use flint, o obsidian is considerably more brittle than flint and therefore more subject to breakage from end shock. However, this substitution o material was done without changing the Corbiac technique; we only slightly modified it t conform to the material. In this case we considered it to be good stoneworking practice Always, techniques have to be adapted from flint to chert, chert to chalcedony, etc. and slightly modified to suit the nature of the material. For example: working with obsidian we had to grind the platform to strengthen it and give a better purchase to the punch (Fig. 5b), decrease the velocity of the blow and detach thicker blades. Bordes had to abandon his reindeer antler hammer and adopt a wapiti antler hammer, lighter and less dense (Fig. 5a and 6a).

After the cobble or mass of material has been selected for blade making, the experimenter must visualize the future core within the cobble. That is, he must calculate how to remove material from the mass in crder to retain as much of the material as possible, and yet properly prepare the core to the desired size. One can never immediately start removing blades from a rounded mass so that the first step of core preparation is to eliminate the rounded surface and establish a first striking platform for preparation of a ridge which is to guide the first blade. This can be done with hammerstones of variable hardness according to the material of which the core is made. An antler billet may be used if there is already a natural facet. Material which is rectangular, without rounded surfaces would be very suitable for core and blade making, but is seldom found. Angular material often has natural longitudinal ridges which may, after slight modification or unifacial trimming, suffice as a ridge to guide the first blade. If the longitudinal ridge is at the corner of a rectangular block of flintlike material, it is relatively simple to prepare the proper platform for the removal of the first blade. Sometimes, just a slight grinding, or preparation by detachinng small flakes at the corner will ready the piece for positioning the punch for blade removal.

Another favorable natural shape is the flat ovoid cobble, with almost angular edges. Once a striking platform is established by a side blow at one end, one can immediately begin taking off blades, the first of which will have its dorsal side completely covered with cortex.

However, if the cobble is rounded and has no natural facet, the worker uses a medium-sized hammerstone to establish the first facet. A hammerstone is necessary, for the antler billet would not have sufficient force to detach a flake from a rounded surface. The worker holds the hammerstone almost vertical to the rounded edge of the cobble and strikes a sharp and strong blow (Fig. 3a) to remove the first flake (Fig. 2a, b). Usually, only one flake is necessary (Fig. 3b) to eliminate the rounded surface.

Preparing the ridge:

To create the first ridge from the bottom to the top of the core (it is usually better to begin at the bottom) the worker uses an antler billet or a soft hammerstone and strikes with sufficient force on the first facet to remove a flake on the other side of the still rounded core. This blow is given in an upward direction (if you begin at the bottom) in order to detach a flake which extends toward the upper end of the core, and is situated along the edge slightly higher than the first flake (Fig. 2b). An antler billet or soft hammerstone and direct percussion is used for this flaking process to prevent the strains and shattering which would result from a harder percussor and also to avoid getting deep negative bulbs, which would make it more difficult to get a straight edge along the core. This is the first step in a series of flakes to be removed in this same manner along the margin of the cobble to establish the ridge. Each scar is used in its turn as the striking platform to remove a further flake, and the worker continues to strike alternately on the edge of the cobble from bottom to top (or the other way around) until the ridge is established (Fig. 2c, d). The edge made in this manner will be sinuous from the alternate flake scars. If the ridge is too accentuated for blade removal it may be straightened by striking off the crests between the lateral flake scars with the antler billet (Fig. 2e). Very often, in Palaeolithic times, much care was devoted to this straightening of the ridge, and so prepared cores, from which no blade has been struck are often confused with tools. The ridge will serve as a guide for removal of the first blade. This first blade removed will create two longitudinal ridges for removal of additional blades and so on around half the circumference of the core (Fig. 4e). If the removal of the first blade is not well done, for instance if the blade breaks at about half the length of the core, it is very often abandoned if the geographical location is rich in flint. If it is a two-ended core, then the second part of the first blade can be removed from the opposite direction and the core can continue to be used. This preparation and follow-through is of the utmost importance because the form and shape of the core control the type of blade detachment.

Preparation of the striking platform:

Before the first blade can be removed a striking platform has to be prepared at one or both ends of the core (Fig. 2f). It is a difficult part of the process and several methods can be used and have been used by Palaeolithic men: (1) striking the core on an anvil stone (Fig. 4b), (2) by direct percussion with a hammerstone (Fig. 3c), (3) by tangential percussion, the core being held on the outside of the thigh which seems to have been the method of the Brandon flintknappers, (4) preparing a small platform on the end of the longitudinal ridge and then severing the top by indirect percussion (Fig. 4c), and (5) preparing a platform by removal of small flakes, like the truncations on truncated blades (Fig. 4a). This method was common enough in Upper Perigordian times, but it is difficult to control and one needs a lot of training to detach the small flakes at the correct angle.

Bordes usually uses methods 2, 3, and 5, but Crabtree favors method 4.

When a core top is severed, the angle of the blow must be calculaed and delivered to create a striking area platform with an angle corresponding with the desired core type. In most Corbiac cores, this platform is oblique to the long axis of the core (Fig. 4f, 5a), but some have a platform at or near a right angle to the axis. This platform angle is the result of the angle at which the force to remove the core top is directed. An interesting feature of the Corbiac cores is that almost all of the two-ended cores

blades taken off from both ends of the core), even if these blades have been flaked off from only one longitudinal side of the core, present on the other longitudinal side a prepared ridge. The one-ended cores, on the other hand, usually present only the natural surface or cortex on the side opposite the ridge (Fig. 2f). This preparation of the second side facilitates the holding of the core between the feet, and in some cases seems to be a kind of precaution against bad handling of the first side. In that case the angle of the striking platform is "reversed," and blades are taken off the second side. Many of the prepared Corbiac cores prior to blade removal, must have looked like thick bifacial implements. Magnificent samples of this preparation have been recently found by M. Duport in a late Magdalenian "cache" in Charente (the Magdalenian technique is almost identical with Upper Perigordian technique). But usually the Corbiac core had blades detached from only one side (one sided), often from the two ends. As blades were removed from the face they created new ridges, this face assumed a polyhedral appearance with long longitudinal facets, and the working edge of the striking platform becomes semi-circular or lunate. In our experiments, we were sometimes successful in detaching as many as thirty usable blades from a core (Fig. 3d). Later when Bordes was giving a demonstration at Washington State University, he successfully detached fifty-three blades from a single core. The first blades are sometimes irregular (Fig. 7d) and it is usually after he fifth or sixth blade that they become really "good" (Fig. 6b). Our cores were abandoned when the platform surface was exhausted and they were left with little or not platform surface. The core was by this time elongated and half-cylindrical, showing blade scars on the rounded side and cortex on the other.

Angle of the core top:

At Corbiac very often the top of the core is designed to slant at less than a 45 degree angle away from the apex (working edge) (Fig. 4f, 5a). This provides a bearing surface for seating the punch and prevents the tip of the punch from slipping when the blow is delivered. Because of the obliquity of the surface on which the punch has to be held, it would be impossible to remove a flake or blade if the platform surface slanted toward the working edge.

Other core types, which usually do not have the top at this angle, overcome the slippage of the punch either by grinding or by removing on the striking platform near the edge, small flakes which leave small depressions (bulbar scars) in which to seat the punch. Rough natural surfaces may also be used. These characteristics are sometimes but not often found on the Corbiac type cores.

Platform preparation:

A small hammerstone is used to prepare the zone on which the tip of the punch will rest. The idea is to isolate a small promontory (Fig. 4a) on which the punch will rest, and which will become the butt of the blade. Isolation is accomplished by holding the hammerstone in the right hand, the core in the left hand (Fig. 5b) and pressing and thrusting the hammerstone downward and outward along the edge of the core, above the pre-established ridge. This action will remove small flakes and shape the promontory without causing hinge or step fractures as would be the case by striking even light blows. This operation is continued until the center of the promontory is above the ridge and in line with the axis of the future blade. This preparation isolates a small but strong striking platform and removes any overhang. Sometimes it is also necessary to complete the preparation by removing small flakes from the top of the core on each side of the promontory (Fig. 4a). (Note: these flakes are removed from the top of the core rather than the leading edge.) For additional strength (mainly when working with obsidian, but this also occurs with flint cores) the platform is then abraded on its top by rubbing with a granular stone (Fig. 5b). This abrasion will round the edges and give a roughly polished appearance to the platform (Fig. 5a).

If the striking platforms are on both ends of the core and blades are removed from both ends, the bi-directional core which results will be sometimes mistakenly called bi-polar. True bi-polarism would be the result of force being delivered simultaneously from both ends of the core.

Seating the core on rest:

When the core has been completely and carefully prepared for the first blade removal (the one which will remove the ridge (Fig. 4d, e), giving a "lame a crete"), it is then placed between the feet on a resiliant support to eliminate shhock at the distal end and also to prevent it from slipping. For our experiments, we used a pine board approximately 2 x 2 x 14 (Fig. 6a).

The blademaker assumes a seated position very slightly elevated above the core; places the core on the rest and holds it tightly between both feet (Fig. 5a). The core is positioned on the rest with the side to be flaked pointed away from the worker with its distal end supported by, but overhanging, the edge of the wooden rest when the core is held vertically. This allows the blades to clear the plank and thereby eliminates breakage. The core is held by the feet in different positions following the type of the core and/or the various problems posed by the detachment of each blade, and also following the preference of the worker.

Detaching blades:

The indirect percussion is done with a "punch." This punch is a cut section of antler (reindeer, red deer, moose, etc.) about six inches long with one end flat and the other shaped to a blunt point (Fig. 6a). It is possible to use a stone punch when working flint, and in Palaeolithic layers elongated pebbles bruised at both ends have been found. This is not satisfactory to use on more brittle material such as obsidian. The punch is held in the left hand (for right-handed persons) and its tip placed and held on the platform at a low angle. This angle varies following the type of core, the angle of the platform of the core to the axis, or the nature of the striking platform: rough natural surface, ground surface, preparation by detaching small flakes, etc.

Using a heavy section of antler about fourteen inches long for the percussor (Fig. 5a, 6a), the right hand delivers a blow of sufficient force to the proximal end of the punch to detach the blade. When working flint, the hammer may be stone instead of antler. The antler punch as well as the antler percussor acts as a shock absorber and causes the force to be delivered more gently to the platform of the proposed blade. Wooden punches may also be used, made of some hard wood, like box wood or oak, and if they are placed at the correct angle on the striking platform, this wooden punch can be used time and again without showing much crushing at its tip. This tip can be hardened by fire.

At present, there is no means of measuring the amount of force necessary to remove a blade from a core, for much depends on the type and size of the material and the blade lengths or thicknesses desired. Since the blade is first detached at the proximal end of the core and then literally peeled down its face, the amount of force is reduced if the butt of the blade is isolated from the core by the "promontory technique" prior to blade detachment. A quick "rule of the thumb" method to determine the necessary amount of force is to calculate the area of the ventral side of the proposed blade and then formulate the amount of force necessary for detachment.

When making blades, to get the best possible results, the same material should consistently be used. One becomes accustomed to controlling the blow on a given material and it may take several days to correlate the amount and kind of force necessary when another material too different in texture and elasticity is used. Some materials are worked best with a sharp blow given at high velocity with no follow through; while others are best worked by using a slow blow with a heavy percussor and a follow through. Blades often leave the core at considerable velocity and must be recovered on some type of soft yielding material (such as grass, moss, sand, etc.) to prevent fracture. In some cases when the force of the blow is perfectly controlled, it happens that the blade just "falls" out of the core.

In our experiments, generally the widths and lengths of the blades were variable and were controlled by the form of the working face of the core. The more attenuated the ridge and the narrower the core, the narrower the blade. The thickness of the blade is also controlled by the position of the punch and the design of the platform in relation to the core. The nearer the punch is placed to the leading edge of the core, the thinner will be the transverse section of the blade. A blade that is triangulate will have the platform oriented in line with the single ridge on the core and the blade that is trapezoidal in transverse section is one that has had the platform oriented between two longitudinal ridges.

Marginal striations on the ventral sides were not noted on flint blades but were quite obvious on blades of obsidian. Any deviations of straightness of the ridge or ridges caused the blades to follow the irregularities and a malformed blade resulted. If differential resistance within the material caused the previous blade scars on the core to be malformed then very often subsequent blades would also be malformed. In some cases the ridge can be straightened by detaching a thick blade which does not follow the irregularities. Another way is sometimes to detach a blade from the other end of the core, and so get rid of the irregularities. If the ridge is prominent enough, it can also be perfected by detaching a series of flakes by lateral blows. This explains why some good blades, taken off the core after many blades have been detached, present on part of their back a "ridge" similar to the "first blade" detached from a core (Fig. 4e). Some imperfections cannot be overcome and then the core must be abandoned or transformed into a flake core.

Should a blade terminate in a step or hinge fracture, at half its intended length for instance, then the core must be either abandoned or corrected if possible. This can be done by detaching a blade from the other end, at reduced velocity, in such a way that this blade terminates at the step or hinge fracture If the fracture was such that it could be taken as a striking platform, one can place the punch on it and so rectify the core. Each error, miscalculation, or imperfection in the material must be considered individually because each presents a different set of problems to the worker. No amount of skill can overcome some of the problems encountered and the core has to be discarded.

For two different knappers the general method can be the same, however different the realization. Bordes makes the Corbiac blades in a seated position with the core held between the feet on a rest, placing the punch at a low angle and striking away, or obliquely, from the body. After he had demonstrated this technique, Crabtree found that he could replicate these blades with this position, but it was more comfortable for him to reverse the striking pattern. He placed the core on the rest between the feet, but with the working surface facing him. He seated the punch on the platform above the ridge at the same angle as Bordes, but with the tip of the punch pointing toward him, instead of away from him, as Bordes does. This was easier and more accurate for him because it did not require leaning so far forward, and also because Crabtree had been doing a similar but different blade technique for the last six months and had become accustomed to this way of working. This position is more dangerous as the blades detach toward the worker, but it has the advantage of permitting the worker to see what is actually happening. Crabtree finds that this variation permitted him to align the punch on the guiding ridge with much greater accuracy and also to actually view the blade detachment. Since the angle of seating the core, striking pattern, punch, and rest are the same in both ways, the characteristics of the blades are also the same. A variant is used by Bordes; the blade is detached laterally, inside the arch of the foot. If the blow is delivered in just the right way, the blade just separates from the core, but rests on the scar.

Characteristics of Upper Perigordian blades:

At Corbiac, and other Upper Perigordian sites, the blades have usually a very small butt (the butt being the part of the core striking platform which is taken away by the blade): it can be either a small circular or semi-circular surface, or a more elongated one (Fig. 7b, c). However, when the butt is wide enough it is often facetted in the "Mousterian way." This facetting is the trace of the striking platform preparation by detachment of small flakes, usually when a thick blade is desired. The size of the butt depends in part on whether the punch has been put on the edge of the striking platform or more inside. Most of the blades with very small platforms have been made by the promontory technique, but it sometimes happens that such a blade is detached without this special preparation of the edge, and one should not conclude, from the presence of some of these blades in an assemblage, that this technique was known to this culture. The presence of this technique is more certain when deduced from the examination of cores.

The angle of the butt on the ventral side of the blade (Fig. 7a, b) depends for the most part on the angle of the striking platform of the core. Here too there are freaks. There is a general if not complete absence of eraillure flakes on the bulb and no fissures radiate from the point of force in the bulbar part. The dorsal part of the blades shows one, two or sometimes more longitudinal ridges. There are very seldom undulations on the ventral side. Most of the time these blades are straight or only a little curved. Crabtree attributes the straightness of the blades to using a rest, for it prevents movement of the core as the blades are detached and simultaneously causes force to be exerted at the base of the core when the blow is delivered on the upper end. Cores not supported by a rest will produce strongly curved blades. This is certainly an important factor, but it seems to Bordes that the shaping of the core also plays a role. Blades from unidirectional cores are more often curved than blades from bidirectional cores, and in some cases Palaeolithic people made special cores to get perfectly straight blades (Fig. 1d).

These blades are further characterized by the frequent absence of undulations and waves of compression, features which are characteristics of those detached from the core by direct percussion with a hard hammerstone. Another distinct feature of the Corbiac blades is their distal end termination (Fig. 6b). The end feathers out without removing any part of the distal end of the core in most cases. This is due in part to the rest, or anvil, and can be controlled to a degree by the angle at which the punch is held.

At Corbiac, where the flint supply was plentiful and the natural nodule huge, blades are often of large dimensions. Blades over 20 centimeters (eight inches) are very common, and most of them have more than 10 centimeters (four inches) in length. But the same technique applies also to small cores, giving two inch blades, or smaller.

Indirect percussion without rest:

Crabtree experimented also with a different and less tiring position of the body. He sat on a little taller stool, placed the core on a pad of folded layers of buffalo hide and held it between his knees for both the preforming of the core and detaching blades (Fig. 8a). This position was more comfortable for him and he was able to make blades with less effort than in the seated position with the core between the teet. However, the blades had then an entirely different character than those made with the other technique, for this method lacked the solid support, or rest, for the core.

Even though the angle of applied force, the type of blow, and the platform preparation were the same, the lack of support on the base of the core allowed the core to be slightly displaced by the blow, and the curvature of the blade was more accentuated (Fig. 7b). Also, the blades did not feather out and they often terminated by taking off a part of the distal end of the core ("lames outrepasses" in French). This knee-holding experiment did show however, that fewer blades were broken because the leather pad acted as a cushion for the dorsal side of the blades, dampening the shock. However it is probable that this method could not produce Corbiac blades with any regularity.

Bordes' observation of this technique led him to a slight modification of his own experiments. He tried wrapping the core in a cloth, or any soft material (like fur) to lessen the shock and prevent the violent propulsion of blades far from the core. This, which did reduce blade breakage, was an adaptation of an experiment he had done in France, coating the external part of the core with clay which gave the same results but was messier. The ideal way, as already pointed out, is to be able to regulate the amount of force of the blow in such a way to detach but not project the blades. This calls for practice and repeated experiments with the same material.

Our experiments in blademaking revealed technological differences which were significant when related to those of the aboriginal. For instance, we noted that blades made by this technique of knee-holding were similar to the Clovis blades illustrated and described by F. E. Green (1963).

The major difference between the Upper Perigordian (or Corbiac) blades and those produced by this technique is in the degree of curvature of the blade and, interestingly enough, is the same difference noted between the Blackwater Draw blades and blades from Upper Perigordian sites. The Blackwater Draw blades have most of the characteristics of the Upper Perigordian blades, except that they are strongly curved, and so resemble those made by indirect percussion without rest. They resemble rather the Aurignacian blades or other cultures for which the straightness of the blades was not overly important. The fact that a rest **is** or **is not** used may appear to be a minor technological trait, but in reality a pronounced curve in the blade indicates a major difference in manufacture. From our experiments, strongly curved blades are the result of leaving the core free to move when the blow is given on the punch, and flat or gently curved blades result from immobilizing the core by a support placed at the distal end, the side of the core being prepared in such a way that it is more or less straight itself. It is interesting to note that a minor change in technology can cause a major change in the type of blades, a change which can sometimes serve as an archaeological index to determine traditions and/or cultural differences in time and space.

In terms of reproducing the sequence of events in blademaking, some of the blades from Blackwater Draw represent the first stages of blade manufacture. These blades bear on the dorsal side the cortical surface of the core, and have a triangular cross section. One of them (Green 1963; Fig. 3d) seems to show on its distal part the ridge of preparation of the core for the first blade. This indicates the aboriginal flintknapper took full advantage of the additional strength provided by the single ridge on the dorsal surface. But this first blade fell short of taking with it all the ridge; part of it stayed on the core and was taken away only later. Following Green, these blades have been used intensively to cut and scrape, even the ones with cortex on one side. These naturally backed knives were already known by the Mcusterians. Other blades from this cache have a trapezoidal section (Green 1963, Fig. 4b, e) and represent blades detached later from the core. This technique is to be distinguished from blades with a trapezoidal cross-section. Blades with triangular cross-section are stronger since there is a greater mass of material than occurs on blades with a trapezoidal cross-section.

If we mentally reconstruct the core from which the curved Clovis blades were detached, it would be quite conical with pronounced curved blade scars on the sides. Also, the angle of striking platforms, in relation to the longitudinal axis, would be the same on the core as is exemplified on the blades. It is a common practice to form a regular surface on the working face of a core by first removing cortex flakes and blades. Blades made during preforming to make the surface of the core regular, have a functional edge and, with the cortex used as backing, they serve as excellent knives and cutting implements. Therefore, it is not surprising that a cache of such blades was found; but it is impractical to assume that the Clovis people defined the sophisticated technique of blademaking and then ceased detachment after the first series of blade removal. It is highly possible that after removing a series of these curved blades, the Clovis people went on to a rest method and ultimately produced straighter blades. This thought is, of course, hypothetical but is certainly substantiated by the Clovis scrapers which give evidence of flatter blades, trapezoidal in cross-section.

Strongly curved blades are unsuitable blanks for projectile points for it would be very difficult to straighten them by flaking both surfaces. Further, Clovis projectile points vary in size and form, and only the smallest could be derived from blades of the dimensions of those from Blackwater Draw (Warnica 1966). The majority of Clovis projectile points were derived from preforms considerably larger than the finished artifact (Agenbroad 1967; Butler 1963; Haynes 1966; Wormington 1957). The indications are that most of the Clovis points were not derived from blades, but rather from large flakes or bifacial blanks formed directly from a nodule or a slab of flint, or chert. Therefore, at present, one can assume that in America as in Europe blademaking encompassed a group of technological traits not directly related to bifacial projectile point manufacture. However, the Clovis blades represented in the Blackwater Draw cache give an incomplete picture and until more blades and, hopefully, cores are unearthed, many technological details will remain uncertain.

Of further note in Green's report is an illustration showing one face of a core from a surface collection in Comanche County, Texas (Green 1963: Fig. 8, 161). It is almost a duplicate of some cores we produced in our experiments with the Upper Perigordian technique. It is a unidirectional core, and the blade scars indicate that the blades should have been flat, not curved, and feathering at their termination. This core seems to show on the left, the lateral flake scars showing the Corbiac type preparation. The blades probably were detached with a punch, the core being poised on a rest, and probably would show a very slight curvature, small striking platforms, and unaccentuated bulbs of force.

Conclusions:

Indirect percussion without rest resulted in typical Blackwater Draw Clovis style blades. However, Bordes points out that when he began making blades with the punch technique he did not use a rest and did not hold the core between the knees. He placed it on the ground and got curved blades with unidirectional cores. So it seems that curved blades indicate a technique in which a hard, or resilent rest is **not** used, while straight blades indicate a hard rest, and probably also a preforming of the core in a slightly different fashion. However, one should not conclude, on the base of **one** or even **a few** blades that such or such technique was used, since sometimes it happens that one gets curved blades with a hard rest, or straight blades with a soft rest, or no rest at all.

The presence of Clovis blades in the New World does not necessarily indicate a blade culture, but only an industry and the knowledge of blademaking. Blades are superb cutting implements, particularly for dismembering large game. Upon becoming dulled, they may be modified into other assorted tools with a minimum of effort. The limited finds of whole blades and cores would seem to indicate a shortage of suitable raw material for making blades. Blademaking is a conservation measure as well as a means of avoiding transportation of surplus material long distances from a quarry.

Blade industries are represented in many parts of the New World from the Arctic to South America. Technologically, blademaking encompasses a wide range of variations and modes of detachment, various flintknapping tools, methods of applying force such as direct percussion, indirect percussion, pressure, and any combination of the three. Numerous techniques and technological traits are represented in both forming and preparation of the surface prior to removing blades. Last but not least the relationship of techniques to the raw material is involved.

Since the discovery of the large, thin, precision flaked bifacial implements at the Simon Site in Idaho, (Butler 1963; Butler and Fitzwater 1965), Don Crabtree has spent much time experimenting with various techniques to resolve this method of thinning. Replicating these implements presented a real challenge for they were thinned by the removal of incredibly large, rapidly expanding flakes from both faces and all margins. Their manufacturing technique was unique because:

(1) The area of fracture of the flake scars on the artifacts is many times the area of the transverse section of the artifact.

(2) The amount of force necessary to remove a flake of this dimension in relation to the thinness of the implement would almost necessarily be too great to detach the flake without breaking the artifact.

(3) The angles of imparted force must be calculated with incredible accuracy.

(4) The intensity of the percussor must be calculated to correspond to the area to be fractured.

(5) The contact point of the percussor and the impact area of the artifact must be diminutive, yet strong enough to withstand the force necessary to remove such a large flake.

All these problems caused me to experiment with various thinning techniques. Although the following described method produces replicas of the Simon material, I cannot resolve this as the actual technique until further experiments are conducted. At the Lithic Technology Conference in Les Eyzies (Jelinek 1965; Smith 1966), Bordes and I had tentatively eliminated a direct percussion technique and also dismissed the possibility of a rest. Now, finally, we had a chance to experiment further with this type of biface thinning.

Thinning of bifaces; first by direct and then by indirect percussion:

Indirect percussion with punch technique was further tried for thinning large bifacial implements such as knives, lance and spear points, large thin discs, and flaked scrapers. This technique includes two phases or steps of fabrication by first direct, and then by indirect percussion. The artifact is first preformed from a large thick flake, or by removing most of the surplus material from a large nodule or rough mass of quarry material, by direct percussion with an antler billet or hammerstone. Then it is later refined with the indirect percussion technique (Fig. 8 a).

Preforming by direct percussion:

(1) The rough material is placed on the thigh of the left leg which is covered with a pad of several layers of buffalo hide. This padding supports the objective piece and, at the same time, dampens the shock induced by the percussor. During the preforming stage of manufacture, the objective piece is held, not on top, but rather on the **outside** of the left thigh. The support provided by the padded thigh relieves the left hand of the entire support of the objective piece and frees the hand to manipulate the piece into position to receive the blows of the percussor. The pad also protects the left hand from bruises and cuts from the flakes as they are detached from the objective piece.

When maximum thinning and formin has been accomplished by direct percussion then the marginal edges are turned, or beveled. This is done by pressing the edges o the artifact on a basalt cobble until the correct angle is attained. The angle is variable depending on the form of the piece bein worked. Then the longitudinal edge is rubbe on the basalt cobble until the leading edg is slightly rounded (Fig. 8 b). This bevelin and grinding strengthens the edges so tha any part of the edge can be used as a striking platform and, therefore, individual platform preparation is eliminated during the nex step of further thinning the artifact by indirec percussion.

Thinning by indirect percussion with punch:

(2) Now that the worker has reached th limitation of thinning and forming the artifact by the direct percussion technique (1), he further refines the piece by indirect percussion with punch (Fig. 8 a).

The objective piece is placed on the pa on the **inside** of the left thigh with its fla side resting on the pad and the leading edg upright for striking to detach flakes on th side resting on the left thigh. The knees ar pressed together to hold the artifact in position. Only the edge of the objective piece i exposed to permit the tip of the punch t be placed on the prepared platform part. I find that the artifact being supported lengthwise on the leather pad and held firmly by the pressure of the thighs has a dampenin effect which reduces the amount of breakag when detaching large thin wide flakes. Th angle of the punch is approximately the sam as that used in detaching blades from the core However, unlike the detaching of blades fro a core, we are not using a ridge to guide th flake removal. Consequently, the lateral edge of the flakes expand. The tip of the punch i oriented in alignment with the horizontal axi of the preform at less than a 45 degree angl while thinning the sides adjacent to the lateral edges. Thinning of the proximal and distal ends is accomplished by placing the tip o the punch at the same angle as above, bu pointed toward the gravitational center of th artifact. Gradually, the angle of the punc is increased as flake removal nears the middle of the artifact. Flakes will have to term inate in the midsection of the artifact, otherwise they will remove the opposite edge.

The punch is struck a sharp, quick blow with no follow through. If a heavy blow is struck with a heavy percussor and a follow through used, the opposite edge of the artifact will be removed. For extreme thinning, a caribou antler percussor is used because caribou has a flared, flat surface and the blow can be delivered on the flat part. This gives a greater contact surface, thereby increasing the accuracy of the blow. Because the weight of the artifact is less than a core, the blow is modified. The worker strikes the punch a short blow with greater velocity which prevents undo movement of the artifact. This allows extreme thinning because it removes a thin, rapidly expanding flake which will terminate in a hinge fracture at the median line of the artifact. The curvature of the flake determines the convexity of the transverse section of the implement. Usually, one entire margin is worked in this manner and then the artifact is reversed and the same technique applied, but having the flakes intersect the previously struck flake scars.

Thinning a biface with this technique is difficult and requires much experimenting to judge the proper intensity of the blow and to dissipate the force before the flake travels across the entire surface of the artifact and removes the opposite edge. This technique produces flake scars which are very similar to those found on the Simon Site material (Butler 1963; Butler and Fitzwater 1965) and Debert bifaces (Byers 1966; MacDonald 1966).

Indirect percussion with foot-holding:

This experiment involves the further thinning of a biface which has been previously preformed with an antler billet and simple direct percussion. After this initial step, the preform is placed on the ground, or a layer of damp sand, held in place by the foot and further thinned by indirect percussion with an antler billet and an antler punch. In this instance, the percussor was a splayed section of reindeer antler.

The platform surfaces of the preform are prepared by beveling and grinding the edge to strengthen it to withstand the force to be applied during flaking. Then the artifact is placed in a horizontal position with the long edge of the beveled side flat on the ground, carefully nested until it is evenly supported by the earth or sand. Then the worker kneels on the right knee with the body bent forward. To stabilize the body, the left knee is positioned at the left side of the upper chest and the left foot is placed on top of the artifact but with the beveled edge exposed. Only slight pressure is exerted on the artifact by the left foot, as too much pressure, or an irregularity of the support, will cause the artifact to be broken when force is imparted to the punch.

The punch is grasped in the left hand by the thumb and fingers and held vertical to the long axis of the artifact, but slanted away from the operator at an obtuse angle. The exact angle is determined by the cross-section of the artifact and by experiment. To insure firm seating, the tip of the punch is placed as near as possible to the leading edge and yet not into the body of the artifact. If the punch is placed too far in from the edge, either an excessively thick flake will be removed or the objective piece will break. Also, if the tip of the punch is placed too far inward from the leading edge, the platform part of the flake will expand and a large lunate section will be removed from the lateral margin of the artifact, causing malformation.

Generally, for the first flake removal, the punch is placed on the lateral margin at the base of the artifact. This is the strongest part of the artifact and therefore permits the experimeter to be fairly bold with the first blow without danger of causing an unpredictable fracture of the object. This blow will be the criterion for further blows and one should examine the results to determine if the flake and scar have the anticipated character. If the flake is too short, then the angle of the punch may be repositioned to direct the force more inward into the body of the implement being fabricated. If the flake is too long, then the angle of the punch is held closer to the body of the worker. The amount of force is delivered in accordance with the size of flake desired. Only experiment can determine the amount of force needed.

Flakes are removed bilaterally from both margins in this same manner and the force is gradually dissipated as the flakes are proportionately reduced in size as the thinning process nears the tip of the artifact. When one margin and one face has been flaked, then the edge is reprepared for removal of the next series of flakes from this same edge but detached from the opposite side.

Our experiments with this technique were successful and we concluded that it had possibilities of having been used aboriginally. However, we felt that additional experiments were necessary before any definite conclusions could be reached.

The techniques of foot-holding and knee-holding (previously described) are the same, except for the manner in which the artifact is held. The one major disadvantage of foot-holding is that the flake is removed from the blind side of the artifact, whereas the knee-holding technique permits instant examination of both flake and flake scars.

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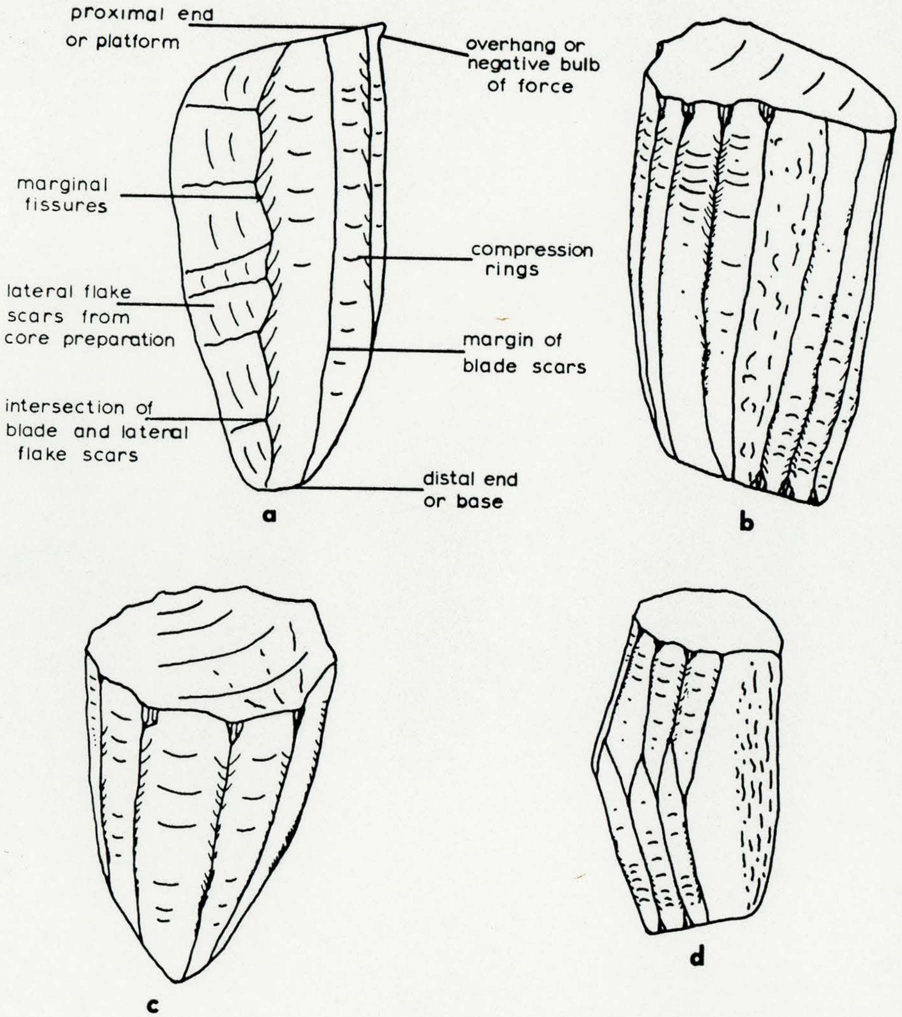

Fig. 1. **a,** unidirectional unifacial core with important features labelled; **b,** bidirectional opposite alternate core; **c,** unidirectional conical or pyramidal core; **d,** bidirectional opposed angular core.

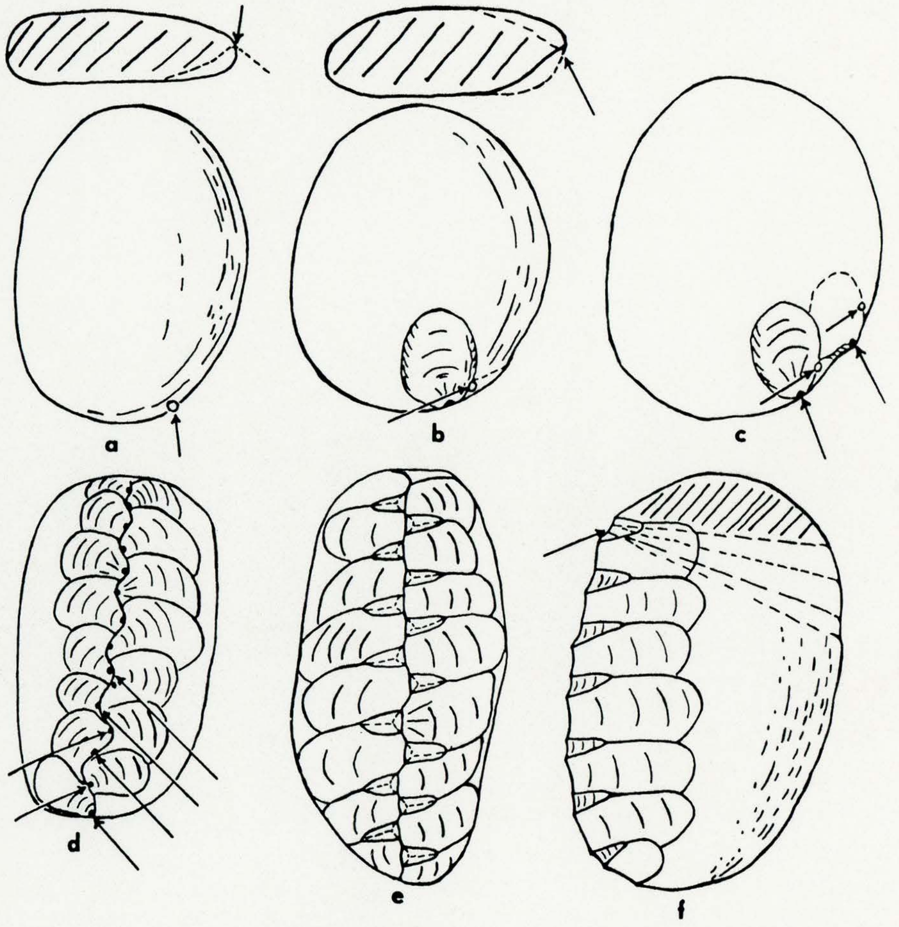

Fig. 2 Stages of preforming a blade core: **a,** removal of first flake; **b & c,** removal of intersecting bifacial flakes to form ridge; **d,** edge view showing bifacially flaked ridge, **e,** edge view showing straightening of ridge by removal of small flakes from margins of lateral flake scars; **f,** side view of core preform showing proposed removal of the end to form the striking platform.