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THE FLINTKNAPPERS 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 mineralogist'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 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 comingled 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 method of identifying good lithic materials is: 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 toolmaker 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. However, if the stone has a sharp ring, 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, they may have lost a great deal of their identity due to pounding and rolling in the water. However, this rolling and pounding gives a clue to the workability of the stone. The 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 superimposed 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 (SiO_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) (SiO_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 & 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 homogeneity, 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) <u>Quartzites and Silicified Sandstone</u>: 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 grains 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 edges 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) <u>Sandstone and Conglomerates</u>: 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

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 tools produced. Since sandstone has so many variations, it is difficult to discuss them all. When one is making an appraisal of sandstone, the first consideration is texture, which is determined by ~~or~~ 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) <u>Conglomerates and Breccias</u>: 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) <u>Bull Quartz</u>: This type of silica is the pegmatite, or vein, variety usually found in ~~the~~ colors of snow white, is opaque and ~~is~~ 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. ~~Bull quartz usually contains strains that are commonly responsible for the opacity and, the poor flakability~~.

(f) <u>Novaculite</u>: 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 BAE Bulletin

(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, tortoise 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 are not as desirable because of the changes of texture between the bands and layers. Chalcedony is the primary material or constituent in the formation of all the cryptocrystalline quartz family rocks. When this form of silica infiltrates, fills voids, blends, infuses, is absorbed and combined with other minerals and their salts, there results the wide range of siliceous materials useful for making flaked tools.

(b) <u>Jasper</u>: Jasper is the result of a combination of chalcedony and argillaceous sediments or residual clays with a simultaneous absorption or infiltration of the two. Frequently the clays will shrink and leave cracks which will fill with chalcedony, giving the material the appearance of being fractured. But, actually, the cracks are well-healed with the chalcedony and a homogeneous mass is created. This type of jasper is a good lithic material and the chalcedony-filled cracks only add to the beauty of the artifact and do not impede the workability of the stone. Jasper which is green in color with red inclusions or spots is normally thought of, and referred to, as bloodstone. Green jasper is opaque while chrysoprase is semi-translucent. Actually, green jasper is only an impure form of chrysoprase. Jasper may occur in various colors. The iron salts in their different valences produce green, red and yellow material and, occasionally, all are represented in the same sample. It would seem that the opaque or impure chalcedony should be classed as a jasper regardless of color. The workability of jasper is the same as chalcedony, since this is based on the amount of impurities and their texture. Most varieties of jasper can be successfully altered by the thermal treatment. I have found only two exceptions: one is a coarse-grained greenish type of silicified clay from Tunisia which was given to me by Dr. Jacques Tixier. By eye, this varved material appeared to be no different from other similar types, yet, when subjected to heat, there was no apparent change in the texture or the workability of the stone. However, we find that the early people of Tunisia altered and worked this material very successfully.

Another unalterable example is an Idaho material called "Bruneau Jasper" from the rhyolite at the bottom of Bruneau Canyon in Southern Idaho. This jasper is much desired as a gemstone because of its very distinctive 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 ~~respond~~ 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 mineralogy 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 translucency 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 workability, 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 differences 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 voids between the microcrystals would then transmit the force from one microcrystal to the next and prevent compression of the flint, thus dampening the force. Less force would then be required to detach a flake in freshly mined flint than in untreated, dehydrated flint. This peculiarity is more noticeable when one is detaching blades from a core by percussion.

High moisture content appears to reduce the brittleness and make the blades slightly more flexible. Personal conversation and correspondence with Dr. Jorgen Meldgaard of the National Museum in Copenhagen revealed some of the European thinking on freshly mined flint. Meldgaard has worked very closely with Andres Kreigh, a skilled flintworker from Jutland and, together, they wrote the book "Mand Og Flint" 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 different 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". ~~That is,~~ 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 I think of as elasticity.~~ 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 leached 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 these colors. Opal is the most brittle of all the silica minerals. Thin edges of opal can easily be flaked by the pressure of the fingernail. Opal with a rich display of colors is considered a precious gemstone but, because of its rarity, played little or no part in the toolmaking industry. It is safe to say, then, that when one sees an artifact made of this fire-quality variety that it may be considered a modern product.

Many types of opal are easily identifiable due to their different physical properties and chemical constituents. Some of the varieties are: precious opal, that showing a brilliant display of blazing colors; girasol, translucent and blueish-white; common opal and semi-opal, that having many colors but without the fire-like reflections; cacholong, that which is opaque and porcelain white; opal-agate, opal of different color shades, sometimes banded; jaspopal, opaque because of the iron salts and other impurities; wood opal, opal silica replacing the substance and structure of wood; hyalite, a very pure form of opal associated with volcanic rocks and occurring in glass-like concretions; fiorite, siliceous sinter; tripolite, consisting of siliceous skeletons of diatoms. It is not uncommon for opal to replace organic materials, the most common being wood, bog and other vegetable substances. Some of the opal replacements are remarkable because of the fidelity with which they replace every cell and fiber of former materials even to such an extent that the original species may be determined. The replacements may, on occasion, be of precious opal such as those found in the Virgin Valley in Northern Nevada. However, it is the common opal, semi-opal, jasper-opal and the agate-opal that are the most common and also the most useful for making stone tools. The fossilized bogs yield this type of opal in more massive beds by replacing the stems, roots, seeds and leaves of extinct flora. These beds are now found in sedimentary deposits as blanket veins. Opal replacements are common where volcanic ash has rapidly covered the organic material.

Opal is not a particularly satisfactory material for making large flaked stone implements. Because of its high water content, it is easily weathered; rapid temperature changes and exposure will result in dehydration, causing the material to crack and craze. The surface, upon drying, will resemble a 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 diagnostic 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 tendancy 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. <u>IGNEOUS ROCKS</u>

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) <u>Obsidian</u>: 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 ~~regain~~ 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 activity.

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 ~~baslat~~ 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-porus 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 ~~these~~ 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 it responds in an identical manner under the application of force. 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) <u>Starch</u>: Starch has much the same character as resin and ~~micro-blades~~ microblades may be removed with the tip of a lead pencil.

(f) <u>Anthracite coal, Cold tar and Gilsinite</u>: 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 analysis is meant to create an interest in the Stone Age materials and to project some of the essentials of lithic material for toolmaking. It is hoped that an understanding of material will create a new interest in the scraps of stone found in campsites and professional digs. Perhaps flakes will have more meaning for the student other than just viewing them as a scrap of worked flint-like material and that, ultimately, these discards may someday help to complete the picture of the past.

III

A suggested list for appraising materials follows:

1. Material: On page 6, Part II, is a compiled 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 material 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. <u>Geological Occurrence</u>: Geological occurrence 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. <u>Light Transmission</u>: 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. <u>Texture</u>: 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 minerals 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 material 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, ~~abraided~~ 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 chance their original structure to one that will lend itself more favorably to the production of certain stone implements. This process will be described more fully in a separate article.