2nd draft

To Vance Haynes

THE MATERIAL OF STONE TOOLS

A basic step in determining working techniques of artifact manufacture is an understanding of the proper stone for toolmaking. [and reconciling the relationship of techniques to material]. This [study and] evaluation of materials is of prime importance not only when interpreting manufacturing techniques, but should also be included in determining typeology. The material used has a direct bearing on methods of manufacture and could even have restricted the toolmaker in the final control of thinness and flaking uniformity. Further, a working knowledge of the stone [to be flake] is essential for the knapper, as any variation in its quality requires a different method of ~~treatment~~ knapping TECHNIQUES [by the worker]. No two materials are exactly alike and, therefore, although the worker's techniques may vary, the basic principles of manufacture remain constant. To [comprehensively understand stone tool manufacturing techniques project the basic relationship of interpretations of the multiple techniques] of men of the Stone Age, we must acquire a more factual understanding of the physical properties of the lithic materials [and how and why they affect the manufacturing techniques].

This is an important introductory statement so may be better not to dilute it with the next phrase which is nebulous to me.

you lost me here

for knapping? (as opposed to grinding)

What are lithic materials? Ideal lithic materials are kinds of stone that have the necessary properties of texture, elasticity ~~and flexibility~~ - relatively free of flaws, cracks and inclusions - that will withstand the proper amount of shock and force necessary to detach a flake of predetermined dimension. My definition of lithic materials is based on my thirty years experience of making stone tools and should not be confused with the mineralogists' definition which generally has reference to the mineral's usefulness in industry, as gemstones, ornaments, gun flints, etc. with emphasis placed on their natural combinations of color, transparency and chemical composition. His definition is aimed at pinpointing properties useful to todays population and mine is to clarify what stone is suitable for fabricating flaked stone artifacts in exact replicas of those of the aboriginal. The result of encountering failure when working unsuitable stone and of success when the physical properties allowed response to the necessary amount of force. Description and explanation will be made of what materials are used in the toolmaking industry, to resolve what stone is adaptable for flaking and to point out some of the working problems related to material that confront a flintknapper.

Desirable material has the properties of elasticity and flexibility, a uniform and even texture and an absence of clevage planes and grain. When this type of material is subjected to the proper amount of force, a cone is formed, and, therefore, portions of the stone can be removed producing flakes with a very sharp cutting edge. This text will endeavor to explain man's ability to control the ~~size, thickness, width and length~~ FORMS of flakes thus detached. When one is able to control the five dimentions - thickness, width, breadth, length and curve - when removing a flake, he can produce most any tool he may need.

What is the difference here?

Massive has a different geological connotation than you mean here

~~The massive~~ Glassey or microcrystalline variet~~y~~ies of silica ~~was~~ were used for flaked toolmaking more than the single crystal of quartz due to the limited supply and distribution of the quartz crystals and the abundance of the massive material. However, the single crystal is very desirable material prized by the writer and apparently the men of prehistory. ~~Quartz,~~ Flint, chert, agate, jasper, chalcedony, etc. in the ~~massive~~ microcrystalline forms are common varieties of quartz used for making flaked tools. Silica in its many forms also plays an important part in the replacement of vegetable and organic materials, the results being fossilized bone, wood, alg~~i~~ae, bogg and others useful for making stone tools. Silica has, for the most part, been deposited by water solution, which has carried the silica to ~~and this circumstance has given it a wide range of intermolecular diffusion found in~~ voids, cavities, seams, crevasses, between pieces of stone and sand, and in spaces left

of certain ~~animal~~ ~~vegetable~~ and ~~mineral~~

after the deterioration of certain animal, vegetable and mineral matter. The varieties of sili~~z~~ca deviate from the single large crystal thru the cryptocrystalline forms to the non-crystalline opal gels. Included is a suggested outline of lithic materials under their workable categories and this may be of some help in material typeology.

My frustrating experience of searching, in vain, for any pertinent information on the relating of minerals to techniques has led me to conclude that the student of lithic technology would be better informed if greater and more exacting reference were made to the materials from which artifacts are made. Terms of reference might be taken from an agreed-upon list of simplified categories that would be universally acceptable. I often find synonomous names being given to the same material for instance, slate being described as metamorphosed clay, metamorphosed sandstone called quartsite, salicified sandstone called quartsite, hornstone called flint, flint called chert, chert called flint, green jasper called bloodstone, etc. When I speak in general terms of artifacts and materials and want to encompass the entire field of adaptable working minerals, I generally use the words "lithic materials", "flint-like materials", or simply "silex". When talking to and comparing notes with other flintknappers, i.e. Dr. Francois Bordes, Dr. Jacques Tixier, and Mr. Gene Titmus, we use these words interchangeably to cover the entire field of lithic materials. I have further noted in personal conversation and correspondence with Bordes, Tixier and Titmus that we will often qualify our material by describing sources - such as "French flint", "Grand Pressigny flint", Swedish flint", "English flint", "Flintridge, Ohio Flint", "Danish flint, "Oregon obsidian, "Idaho Ign~~y~~imbrite", etc. This gives immediate identification of material and conjures up a quick mental picture of the minerals and the problems or bonus qualities contained therein.

Is this acceptable or will it be more familiar to readers as a trade name and therefore be confusing?

Some European archaeologists havecombined and grouped most of the working qualities of stone and listed them under the single heading of "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. In my vocabulary, the words silex and flint are synonomous, but I only make this reference when speaking of materials generally and not specifically.

Many mineral names for lithic materials reflect a consideration of transparency, degree of conchoidal fracture, hardness and chemical constituants. However, to the stoneworker, these attributes have little meaning for his interest is in the isotropic properties of the given material. Even though there is a relationship to isotropism and conchoidal fracture, the final results when testing depend on the surface and the conformation of the material. In other words, ~~on~~ the same a block of ~~good~~ material from which a variety of flakes - flat, curved and of various dimensions - may be removed, depending on how and where the force is applied. The termination and shape of the flakes are controlled by the desires of the person applying the force and, therefore, do not always resemble the shell-like or conchoidal fracture.

The stoneworkers first concern in choosing working material is quality of texture. The fineness or coarseness of the micro-crystalline structure of the material when it was formed will determine the texture. Opal, obsidian and ign~~u~~imbrites are exceptions. Opal is a silica gel with no apparent crystall~~ography~~inity; while obsidian is a volcanic glass and ign~~u~~imbrite a welded volcanic ash. The texture of the microcrystalline varieties determines, to a degree, the toughness and tenacity of the material. The intertwining of the microcrystalline particles or aggregates ~~structure~~ produces a fibrous character that resists the detachment ~~of flakes by either pressure or percussion.~~

of flakes by either pressure or percussion. The more coarsely textured materials have toughness but their flexibility is lessened due to the fact that the micro crystals have areas of weakness between them and, therefore, tend to collapse before long thin flakes can be removed.

However, the platform prepared on coarse material will collapse more readily than that fabricated on finer textured material. Generally the coarser the stone texture, the tougher and the more difficult it is to work. The tougher the stone, the more difficult it becomes to remove regular and uniform flakes. Natural weaknesses The character of the stone are is also important, i.e. bedding planes, inclusions, incipient cracks and internal stresses, etc. While color and transparency will produce a more colorful and beautiful tool, they are not necessary properties pf good lithic material.

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 Berkley, 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 utalized and the resulting array of flakes was 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.

Other means of identifying properties of good lithic materials are: texture, luster, surface character, cortex(or rind), color, transparency, sound, ~~flexibility, sharpness of the removed flakes~~

flexibility, sharpness of the removed flakes and perhaps most important is the amount of resistance to the necessary force required for detaching a flake. The degree of luster is used as a guide by flakers 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. The variations of luster include glassy, waxy, greasy, satiny to dull, matt, flat, sugary, fine crystalline, medium crystalline, coarse crystalline and sandy. The refractive index als~~m~~o may serve to determine the degree of fineness or coarseness of material.

Most sources of lithic materials produce a material that is identifiable through special qualities recognized by the stoneworker. He must, when choosing material, determine the homogeneity of the mass and appraise the texture and luster of the stone and fit the size of the rough material to what he wants in a finished tool. The myriad of bright colors are desirable, but color in most instances, does not indicate workability of stone. In making an appraisal of the flint-like materials to determine their workability, one may first tap the stone lightly to prevent brusing 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 manufacturing of an artifact. The final outcome will, of course, depend on the skill of the worker.

When hunting suitable material in the field, I find the most satisfactory method of testing is to drag the fingernail across a freshly flaked surface to denote its qualifications. If the fingernail moves easily across the surface, I can assume the material is fine~~ly-~~grained. If it hangs up or drags, then I presume the material to be coarse~~-~~grained.

Some material is still available in certain gravel [alluvial] deposits [with new exposures.] l.c. In which [these deposits of cobbles,] one may identify, by examining the surface texture of the individual stones, the material that will best lend itself to flaking. If one is not familiar with the nature of the stone then appraisal will be more difficult and testing of each cobble would be necessary. Water-worn cobbles lose a great deal of their identity as a result of pounding and rolling in the water, l.c. However, this [rolling and pounding, fortunately,] 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, that is [Upon examination, one will find that, in reality, each bruise is] actually a cone. Some are obvious - others are visable circular scars just under the surface. If one will examine a well-used glass marble, he will readily see the type of scars I am referring to. It is this type of a scarred surface that is so important in determining the materials usefulness to the stone flaker. The multitude of cones are superimposed at random and intersect one another. Under certain conditions, moisture will enter the incipient circular cracks then,at low temperatures, freeze and loosen the portions of stone between the cones. The surface is actually a multitude of little exposed cones, reminiscent of the surface of the moon - or similar to what we laughingly call "goose bumps". The recessed or concave protected areas often receive a polish from being burnished without shock against one another and do not have cones. By these types of surfaces, one is able to identify the cobble that has the desirable working properties. Stone lacking this type of surface can be assumed to be without conchoidal fracture [granular] and unfit for the manufacture of stone artifacts.

even cherts are granular

As a source of material, surface finds are easier to secure than material which must be dug. In most areas of this kind, a person will find a few broken tools made from this material. From the size of the broken tools, the aboriginal stoneworker had uncanny ability in finding the best and most colorful quality material in massive form. Today, usually a deposit of this kind yields only pieces under six inches in diameter, and finding a nodule as large as a basketball is a rare event [as the bubbles in the molten lava must have burst or risen to the surface before the lava solidified]. how does this relate? Occasionally, fissures and cracks will fill with agate, chalcedony and jasper and when they weather out they are in large tabular pieces ideally suited for the making of large bifacial tools. Some of the silica minerals deposited in the cracks and crevasses will form tabular pieces of usable material that is of ideal thickness for making thin knives and projectile points, thus eliminating percussion preforming.

When such material is available, one may complete the tool by the use of pressure alone. In some instances, when this thin material was used, the entire surface was not removed by the pressure retouch. When this happened, and a flat portion of the original surface on each side of a bifacial implement remained, it could be diagnostic in determining the source of the material. However, the source of material is difficult to determine on a finished bifacial artifact if all of the original surface is removed. Then the flakes discarded by the workman are of more value than the finished artifact in determining the location source of the material. Sometimes, The dorsal side of some of the flakes will show the natural surface of the material, and this will, in most cases, indicate whether it was quarried, secured from alluvial deposits, veins or weathered from the surface.

In my search for good material, I look for the purest forms of silica in massive homogenous cryptocrystalline form, for the type of crystall~~ography~~inity is of utmost importance. I hunt for a flawless type of stone, without grain or clevage plane - of adequate size - which has the inherent strength to tolerate the application of pressure or percussion and yet fracture in any direction to terminate in a sharp edge. Selection can range from the non-crystalline amorphous opal to the massive quartz crystal. The silicification by hydro-thermal waters deposition and aqueous solution ~~saturation of silica charged waters~~ altered many of the normally usuable rocks to ones that are now useful for making flaked stone implements. It is, indeed, fortunate that a large portion of the earth's crust is made up of the combination of the two most plentiful elements - silicon and oxygen, or silicon-dioxide. It is the combination of this compound with not too common elements and trace-elements that gave the stoneworker such a wide range of material which was adaptable for the production of flaked stone implements.

A few examples of this sort of impregnation of silica-charged waters are the silicification ~~fossilization~~ of boggs and swamps, silts and sands. It is of interest that some forms of silica have an affinity for organic material - comparable to the chemical reaction, or attraction, of a cotton string immersed in a saturated solution of salt water. Many occurances of flint are known to contain fossils, such as the flints from England, Denmark and France. Also, the concretionary nodules of Southern Indiana and Illinois usually have a bit of organic fossil remains in the center. Some of these fossils cause imperfections in the flint tools much to the chagrin of the worker.

The silica minerals which I have used in my experiments to reproduce prehistoric tools are similar to, or the same as those used by the prehistoric stoneworkers. Because my home has been in Idaho, I have had to gather the major portion of my experimental materials from the West with small quantities being given and sent to me from other parts of the United States and Abroad.

This has given me the advantage of living in a sparsely populated area where lithic materials were fairly abundant, but the disadvantage of not being able to study enough collections to permit viewing and comparing a larger array of materials used by ~~the~~ aborigin~~als~~les. During the many years I roamed the deserts in search of material, I always found, upon discovering a source of good rock, that ancient man had been there before me and had quarried out the same material for his tools. Further, it always seemed that the massive material he left behind I, too, rejected and for the same reasons, i.e. imperfections in the stone, flaws, fractures, too granular, crystal pockets, etc. Finding an undisturbed source of good material suitable for tools has been a marjor problem since I first started my experiments. The first materials I used for fabrication were the rejects and cast-offs of the Indians. The disadvantage of using cast-offs was the irregularity of the flakes and the short supply. Somehow, I could never seem to find massive material that quite matched the flakes and cast-offs of the campground. Because of this, I became suspicious of Paleo-man altering some of the flint-like materials. From this deduction and further experimenting, I found their secret of altering lithic materials by the thermal treatment (Crabtree and Butler)

But, in the beginning, I only knew that I was attracted to their cast-off flakes because of the change in color, the shiny luster and the ease with which their discards worked. During these years, I have visited many sources of material and quarry sites and have yet to find one that was not previously visited and worked by ancient man. After taking what was left over, after centuries and millenia use by prehistoric man, I now have to contend with the present-day hunters called "rockhounds".

Finding good workable material is most important for certain materials will allow the platform to collapse - leaving a dull edge - while others haven't sufficient strength or flexibility to permit making a long thin flake - thereby causing multiple hinge and step-fractures. Personally, I cannot do the fine type of controlled pressure flaking on coarse-grained materials that I can achieve with finer, more closely-grained stone and, from the few collections I have been able to study, I have noted this same type of material restriction. Therefore, I conclude it is most important to consider material in our analysis of tools, our explanation of type, and the study of technology.

Often I have heard reference being made to a large thick biface, irregularly surface-flaked as "crude heavy biface" or "crude percussion work", whereas, in reality, the worker was a skilled craftsman to have produced any type of tool considering the material he had to work with. I have also heard this same reference being made to pressure work on poor material whereas the presence of any control at all denoted a skilled craftsman. A stoneknapper will always relate the quality of workmanship to the material.

Years ago when working in the East, I had the unhappy experience of seeing the quality of flint based on the quality of work done by the past stoneworkers - assuming when beautiful precision work was accomplished that the flint was of good quality and could be worked like cheese. Fine quality material does work better and produce precision flaking, but this cannot be used as a basis for judging the quality of flint, for one may find a good quality material poorly flaked which is just the result of an unskilled workman. This may seem to be discordant with my plea to relate techniques to material. However, this is not the case. Poor material showing skilled and controlled surface techniques does indicate 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 for we must keep in mind the human factor of finding good work on good stone and poor work on good material; and good work on poor stone and ppor work on poor material. We must also keep in mind that there are those who do not recognize thermally treated stone and they may be viewing this heated stone and calling it good flint whereas it could actually be an inferior stone improved by heat treatment. When we do find poor work on quality stone then I think it is safe to assume we are viewing poor workmanship, unless we find, on inspection, that the worker was merely preforming good material which was later to receive the refined techniques. One can relate techniques to material but we cannot relate material to techniques - the old story of the chicken and the egg.

Because of the close relationship between material and techniques we must be careful to judge character of the material before we appraise the quality of the work. Quality of material plays a great part in the resultant uniformity of flaking, thinness of the artifact, and may even have guided the worker in deciding whether or not he could detach uniform flakes with precision, control and regularity, either by pressure or percussion.

VARIETIES OF LITHIC MATERIALS

(1)

CRYSTALLINE VARIETIES OF SILICA

Rock Crystal
Quartzites
Sandstones, Conglomerates, Breccias
Bull Quartz
Novaculite

(2)

CRYPTOCRYSTALLINE VARIETIES OF SILICA (Si 02)

2A Chalcedony
Chalcedonic Rocks
Agate
  ~~Eye~~
  ~~Tube~~
  ~~Fortification~~
  ~~Tortoise Shell~~
  ~~Mocha Stone~~
  ~~Scenic~~
  ~~Moss~~
  ~~Plume~~
  ~~Iris~~
  ~~Shadow~~
  ~~Bamded~~

local terms with little overall significance could add 100's more so why not omit?

Onyx
Sard
Sardonyx
Chrysoprase
Jasper
Bloodstone
Organic Replacements
  Casts
  Wood
  Bog
  Algae, etc.

2B Flint
Chert
Hornstone
Lydianstone
Touchstone

(3)

NON-CRYSTALLINE VARIETIES OF SILICA (Silica Gels) Si 02) plus H2O

Opal
Opalite
Silica Gels
Opalized Wood
  Bog
  Organic Replacements
Obsidian
Pitchstone
other volcanic glass

(4)

IGNEOUS ROCKS

Obsidian
Pitchstone
Ignimbrite
Basalt
Rhyolite
Andesite
Felsite
TEKTITE

(5)

SILIC~~EOUS~~IFIED 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
Coldtar
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.

1. Crystalline varieties of silica. The crystals detectable by eye.
2. Cryptocrystalline varieties of silica. Siliceous material of the massive homogeneous variety with hidden indistinguishable micro-crystals.
3. The non-crystalline varieties of silica.

   These three groups are, by far, the most common used by both past and present stoneworkers.
4. Igneous Rocks. This group is not a part of the quartz family, but, when available, played an important part as a source of material.
5. Siliceous sediments. This group played a fairly important part as a source of material.
6. The fine-grained metamorphic rocks
7. The exotics. Materials of nebulous and unknown classification.
8. Experimental materials. Materials used for student demonstrations.

CRYSTALLINE VARIETIES OF SILICA

Quartz Crystal:

The natural crystal form, easily recoganizable. The use of this variety for making tools is very rare. Sources containing crystals large enough to make tools of adequate size do not have a wide enough distribution to play a major part in the source of material. When quartz crystal is used in the manufacture of flaked tools, it must be treated differently than the cryptocrystalline varieties. Quartz crystal is formed in the hexagonal system formed 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 homogenety, the more tightly joined the growth planes, the better the material. Some varieties of crystal have 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 clevage planes of the growth pattern. The resulting artifact will be thick and ill-formed and no amount of skill can overcome the physical properties due to the weakness in the crystal planes of poorly oriented artifacts.

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 desired 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 flexibility. 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 quartz. 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 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. Techniques are limited to percussion.

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 nature supplied when forming the sandstone 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 - or the size and kinds of sand - and the joining of the grains whether by silica or calcium carbonate. A further appraisal would be the sonorous tone produced by striking the stone with a hammer. If striking the material produces a musical ring, it will indicate good working quality. However, if the stone has a sound-absorbing surface, producing a dull thud, this will indicate a poor quality material. 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.

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 homogenety and texture, then we have a material that is ideally suited for toolmaking.

Bull Quartz:

This type of silica is the pegmatite, or vein, variety usually found in the colors of snow white, opaque and is sometimes 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, of course, the poor flakability.

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 salicified sandstone. W.H. Holmes(Bulletin 60,1919, page 196-200) describes novaculite as being the same as cherts and chalcedonies and with some having color. At present, I cannot attest to the workability of this material as my samples are not of sufficient size to permit me to determine the flaking qualities. Since the word "novaculite" is used and accepted, I make bare mention of it here until a further study can be made to determine if it has qualities that will distinguish it from other materials.

CRYPTOCRYSTALLINE VARIETIES OF SILICA

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 - yellowish, amber, orangeish, redish, 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. The very popular hobbyists called "rockhounds" have many sub-titles and many "ites" to identify the various forms of agate and chalcedony and, I might add, that they are surprisingly well-informed on 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 variety, or what might be called a "rust" color. 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 constituant 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 silicious materials useful for making flaked tools and artifacts.

Jasper:

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 homogenous 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 that 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 producing green, red and yellow material and, occasionally, all being 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 - both basing their degree of workability on the amount of impurities and the quality of 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 than other similar types of this type of stone, yet, when subjected to heat, there was no apparent change in the texture or the workability of the stone. Yet 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 aborigional man in that area. Early man was able to alter this stone, but, so far, I have had no success with the thermal treatment of this material. Perhaps, with further experiments and an analysis of the components, we may determine the differences between varieties of jasper. 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.

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 micro-crystals 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.

Flint-like Materials:

Flint has a wide range of forms, textures, colors, and occurances and there are those who usually consider any hard, tough stone to be flint and generally consider most arrowheads to be 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 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 to further clarify and represent the inherent qualities of each source. 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, on flint may appear to be of the exact nature of that from a different site - yet, when subjected to the percussion method of detaching flakes, it does not respond 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. There appears to be much disagreement in definition - some define chert as an impure flint, while others maintain that flint is an impure chert. (Sir.Chas Lydell, F.B. Loomis, E.H. Kraus, W.F. Hunt, Sir Archibald Geike, and many others) Others argue that chert and flint are the same. (A.P. Brigham, "Textbook of Geology",1901, page 194) 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 homogenity 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. Also, 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. However, 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 gigen to me in 1940 which I recently made 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 and 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

The purpose of heating the flint is not to remove been dehydrated. The purpose of heating the flint is not to remove the moisture, but to aneal the stone by changing its crystall~~ography~~inity, 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 of flaking ability whether by pressure or percussion. On the other hand, freshly mined saturated flint would have additional strength because the water filled voids between the micro-crystals would then transmit the force from one micro-crystal to the next and, at the same time, 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, 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 each individual material separately rather than generalize [judge its workability according to whether it is freshly mined or surface - dehydrated or hydrated]. 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 - that is, greater control may be exercised in removing flakes of a desired and given dimension. 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, it 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 in. 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 permiate 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 substances is a suitable analogy.

However, the development and growth of a nodule of flint has no divisions between the layers of silicious 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 micro-crystalline 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, permits one to create a platform that will withstand the necessary pressure or percussion force without collapsing, thereby permitting a wide thin flake to be detached without breaking off short which causes step-fractures. Flint has a resistance to "end shock". That is, when the blades are removed from the 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 [redacted] [redacted] blade. This I think of as 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 micro-crystal size. For example: a non-crystalline material, such as obsidian and opal, when cleaved or a flake removed, will break to the last molicule or to a theoritical infinity; while flint will break to the last micro-crystal, 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 pin-point 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 synoonomous and the mineral constituants are dissimilar. A breakdown of the individual flints that have individual characteristics could be useful in determining their aboriginal source and the trade and migrational 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
do you mean radioactive?
difference in the unstable elements contained in one that is lacking
SOLUBLE carbon dioxide H_2CO_3 do you mean in the earth
in the other. The amount of CO2 - or carbonic acid - in association yes
with worked flakes or tools could also have a direct bearing on the rate in 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.

NON-CRYSTALLINE VARIETIES OF SILICA

Opal - Non-crystalline amorphous silica

Group number three is the non-crystalline varieties of silica. It is in this group that we have precious opal, common opal, opalite, diatomite and the various other 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. Opal 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 rarety, 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 as pseudo.

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~~s~~ 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 occuring in glass-like concretions; fiorite - silicious sinter; tripolite - consisting of silicious skeletons of diatomes.

Opal is not a particularly satisfactory material for making large flaked stone implements. Because of its highwater content, it is a very unstable stone and 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. 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 [and bend] 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.

Artifacts made from opal are scarce and when one if found with the luster of opal it is more likely to be of a heat-treated cryptocrystalline variety of quartz rather than opal - or the non-crystalline type of silica. 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 attacted and dissolved, leaving the layers of chalcedony unaffected.

Common opal and semi-opal are the only varieties of opal that are useful for making flaked tools. The other varieties listed above are of little or no importance to the lithic industries. However, there appears to be a need for further research on the combinations of crystalline and non-crystalline varieties of ~~quartz~~ 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.

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, with minute accuracy, 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 very easily flaked - it has a high degree of flexibility, probably the highest degree of this particular physical property of any of the lithic materials. By comparison with other material, opal requires little pressure to detach a flake. Therefore, it is an interesting practice material as the flaking can be controlled and long narrow flakes detached.~~

IGNEOUS ROCKS

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

1. Obsidian, a volcanic glass of granite composition
2. Pitchstone, an opaque ~~coarser~~ grade of obsidian
3. Ignimbrite, a welded volcanic tuff.
4. Basalt, a type of extrusive volcanic rock
5. Rhyolite, a light-colored volcanic rock
6. Andesite, a volcanic intermediate between basalt and rhyolite in composition
7. Felsite, the name used for both rhyolite and andesite when a more accurate identification is impossible.

Obsidian

A volcanic glass of granite composition [consisting of lime or potash and silicate with alumina and iron, ~~usually found in connection with feldspars~~]. 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 is 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 Meso-america 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 ther is no monotony in the endless varieties of swirls, bands, colors, irridescence 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, Meso-America, South America, Iceland and, to some extent, in the Mediterranean area and in Africa. It was employed in the manufacturing of cutting implements, tools, projectile points, utensils and mirrors. 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 cristobalite 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 size 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 a crystalline form, making the older material unpredictible 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 aborigional 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 - it may occur very soon after extrusion as a result of hydrothermal activity.

Gene Titmus, Henry Irwin and the writer 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 and the cobbles found at the Glass Butte site. When struck, the Burns obsidian has a resonance that is unnoticable in the Glass Butte material. Until one is able to mentally calculate and compensate for the difference in toughness and homogenity 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: ICELAND 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; near Cederville, California; Coso Hot Springs near Little Lake, California; Glass Mountain northwest of Bishop, California; Fish Lake, Nevada; Clear Lake, California; Snowflake obsidian south of Salt Lake City, Utah; Iceland; the Western slope of the Tetons, Idahp; Sweet, Idaho; ~~and~~ Owyhee County, Idaho, and Iceland

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.

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.

Ignimbrite

A type of volcanic rock easily confused with obsidian. It is, however, a welded volcanic tuff and breccias. 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 signs 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 ignumbrite 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.

Basalt:

Is 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 the 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. 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 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 - those used to cut antler, bone or wood. The basalt tool is used in a saw-like manner.

Rhyolite:

Rhyolite is 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 to good quality heat-treated jasper and chalcedony in degree of workability.

Andesites:

Andesites, because of their abundance and variety of color, texture and mineral composition are suitable for certain type artifacts. They are, in general, darker than rhyolites and the dark grey color is common. They are transitional on 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 - a distinction from rhyolite. Because of the wide range of constituents, textures and contained minerals, the degrees of workability are relative to the homogenity and texture of the andesite.

Felsite:

It is difficult to discriminate between rhyolites and andesites that are devoid of phenocrysts, making it necessary to use an elastic, noncommital 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 occurance 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 - the final analysis will have to be left to the mineralogists.

TEKTITES, Glasslike material of possible extraterrestial origin found and used aboriginaly in australia and India, experiments were not done in this material because none were available.

SILICEOUS SEDIMENTARY:

Welded Permeable rocks:

The impregnation of permiable 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 permiable 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.

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 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 tallus or in alluvial deposits. The siliceous sedimentary rocks are usually in tabular form often with varves and bedding planes. The sedimentary material having clevage 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.

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

Siliceous Limestones:

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 usuable 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 constituants. 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.

Metamorphosed Rock:

Metsmorphic 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.

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.

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.

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.

EXPERIMENTAL MATERIALS

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, the step and hinge fractures, the errailures, the flake overlaps, the platforms and the bulbs of force well defined. The glasses 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 of the historical sites in the Americas. It was a favorite of the Australian aboriginies and a great majority 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. One must keep in mind, however, that unless one is doing this work continually, the hands will become very tender until the muscles are hardened and callouses are formed.

Glass as an experimental material is easy to obtain in a variety of shapes, forms, colors and composition. An excellant source of supply in the Archaeological sites of the future, i.e. the city dumpgrounds - 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.

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.

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.

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.

Starch:

Starch has much the same character as resin and micro-blades may be removed with the tip of a lead pencil.

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 typeologist. It is not the purposes 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 Stoneage 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 and that they 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.

A suggested list for appraising materials follows:

1. Material On page 13 is a compiled list of various kinds of lithic materials including some seven groups and sub-classes. 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 excellant 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. Geological Occurence 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 usable 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 servs to bring out the true color of the

reflected light and, at the same time, aids in revealing the structure which may be characteristic to 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 vitrious - 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 excellant 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 micro-crystals. 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 experimentors 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 yeilding 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-donvex 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, o of nodules or masses of flint whether from chalk or limestone deposits. The bruised, abraided 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 silicious 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 silicious 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 will be described more fully in a seperate article.