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In the final analysis, the profession must judge Ancient Man, interpret his habits and movements and project their conclusions primarily on what he left behind made with his hands. So what better criteria for the Lithic Period than an appraisal of his stone implements, an analysis of the discarded flakes and the debitage resulting from their production, a study of his working techniques - together with an appraisal of the material from which the tools were made. To complete the picture and more fully relate techniques to material, it would be well, if possible, to orient stone sources and determine the extent of their geographical range. When a stoneworker wanted to make a tool or artifact, his first thought was what type of implement do I want and where is the nearest source of satisfactory, adaptable material. If this first step in tool manufacture was a concern for workable stone, it would seem that material should also be our first step in analysis.

Understanding what types of stone Ancient Man used for making his implements is a basic step in the final analysis of determining working techniques and before we can actually discuss and analyze, step-by-step, the actual manufacturing process of toolmaking, we must determine what type of stone prehistoric man used for his implements and reconcile the relationship of techniques to material. We cannot exclude material from this analysis, for the stone, itself, is an integral part of the tool and, therefore, must be appraised simultaneously with the techniques. This study and evaluation of lithic materials is of prime importance not only when interpreting manufacturing techniques, but should also be included in determining typeology. I cannot overemphasize the importance of this appraisal, for 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 flaked is essential for the knapper, as any variation in its quality requires a different method of treatment by the worker. No two materials are exactly alike and, therefore, the worker's techniques may vary but the principles of working the tools remain the same and constant. Only a stoneworker can fully appreciate the problems involved with different materials and be aware that the stone, itself, may restrict or govern what the worker produces. I can only conclude, therefore, that to comprehensively 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.

What are lithic materials? Lithic materials are forms 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 a predetermined dimention. This will be further explained and clarified under individual materials. My definition of lithic materials is based on the results I have noted during the many years I have worked stone - failure when working unsuitable stone and success when the physical properties allowed response to the necessary amount of force. My description of certain minerals may not agree with today's mineralogists, but they are the result of many years of success and failure in percussion and pressure flaking various stones and will reflect a stoneworker's perspective of lithic materials. This paper will not attempt to compete with or contradict the mineralogists, for my research has shown that there is much disagreement and difference of opinion in this field, and following their terms, to the letter, would only confuse ~~the~~ reader. My attempt will be to describe and explain what minerals 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 confronts a ~~to~~ flintknapper. My conclusions and definitions of materials reflect the viewpoint of a stoneworker and his actual needs and appraisal of workable material suitable for flaked implements. Ancient man MUST HAVE had an uncanny, instinctive knowledge of lithic materials which was acquired, no doubt, by need and the trial and error method. Because he understood the physical properties of lithic material so well and inherited the accumulated knowledge of his ancestors, he was able, mentally, to invent working techniques that could not be accomplished accidentally - but had to be the result of much reason, ingenuity and skill.

Suggestions will be made for the use and variation of known and accepted mineralogical terms but no attempt will be made to resolve the problems relating to material typeology. These typeology problems I hope will be solved by the present advancement of scientific research - particularly applied to the analysis of inorganic materials used in aboraginal flaked stone implements. Great strides are being made in the field of neutron activation analysis and, by using this process, some seventy microconstituents may be identifed even though some are as rare as one part in a billion. This process can analyze an object that weighs as little as one ten billionth of a gram. The material examined is not destroyed or mutilated - as usually happens in chemical analysis - and the basic composition remains unchanged. The use of this method may broaden the field of relating stone artifacts, surface and otherwise, to their point of origin thereby depicting their movements through time and space.

Quartz, SiO2, known as silicon dioxide makes up the majority of the earth's crust. It is this group of quartz family minerals that are primarily used for making flaked stone tools; i.e., the homogeneous cryptocrystalline variety. Had it not been for the availability of the dioxide of silicon, one of the most abundant of all compounds, it is doubtful if Ancient Man could have found a substitute to use for carving and shaping tools of bone, antler, wood and softer stones, and without this silicon compound, it is doubtful that homosapiens would have atteined our present day level of civilization.

Amond stoneworkers, quartz was the most prized, the most beautiful and the most varied of all minerals because of its color, form and physical constitution. It assumes so many phases and, is intermitently graded from one extreme to the other under so many links of conditions, that its complete description and a pin-point analysis is almost impossible. In this group of quartz family minerals, it is primarily the cryptocrystalline varieties that are most adaptable for making flaked stone tools. The desirable varieties have 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 right kind of force, a cone is formed. The cone is an integral part of the proximal end of the positive flake. Complete explanation of the cone will be given later in this book.

The hardness of silex or silica is exceeded only by three minerals - the topaz, sapphire and the diamond. The homogeneous variety of silex (flint-like materials) has the property known as isotropic(glass-like) quality. Because of this physical property, cleaving or striking the material results in a chonchoidal fracture and it is this quality that permits a flake to be detached by pressure or percussion.

When subjected to the proper amount of force, applied on a properly prepared platform, portions of the stone can be removed producing flakes with a very sharp cutting edge. The following text will endeavor to further explain man's ability to control the size, thickness, width and length 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 then produce most any tool he may need.

The massive variety of quartz was used for flaked toolmaking more than the single crystal form 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 toolmaker and apparently the men of prehistory. Quartz, flint, chert, agate, jasper, chalcedony, etc. in the massive forms are much more common varieties to be used for making flaked tools. Quartz in it s many forms also plays an important part in the replacement of vegetable and organic materials, the results being fossilized bone, wood algie, bogg and others useful for making stone tools. Quartz has, for the most part, been deposited by water solution, and this circumstance has given it a wide range of intermolecular disfusion found in voids, cavities, seams, crevasses, between pieces of stone and sand, and in spaces left after the deterioration of certain animal, vegetable and mineral matter. The varieties of quartz deviate from the single large crystal thru the cryptocrystalline forms to the non-crystalline opal gels. During the formation, the indispersement and assimilation of iron and other metallic salts, in variable amounts, resulted in materials having a wide range of character, texture and color combinations. It is possible that the absorbed salts of trace elements could be a clue in reconciling the source and distribution of material from which stone artifacts were made.

In researching mineralogy, I generally find that the lithic materials are described with regard to their usefulness as gemstones, ornaments, gun flints, etc. with emphasis placed on their natural combinations of color and transparency. This results in much confusion and overlapping of names, and creates disagreement regarding the fine lines drawn between the blending and infusion of the quartz family minerals. The present-day myriad of mineralogical terms may be very useful for those in that field, but they are sometimes confusing when applied to lithic materials. It is for this reason that I feel the profession should use their terms but should qualify them so that they can be universally understood by the student of lithology. For example, it would be well to drop the synonomous terms of hornstone and flint, lydianstone and flint, touchstone and flint - stop the reversing of flint and chert, chert and flint - delete the snyonomous use of agate-jasper, jasper-agate, green silex and green jasper, etc. and, instead, conscientiously try to agree uniformally on a usage of words relating to lithic material categories.

Not only would it be useful but would simplify the understanding of lithic materials, clarify descriptions, and create a uniformity if the profession would create a systematic uniform classification of general categories - with subdivisions - for lithic material study. Too many names are synonomous and this results in a different meaning and interpretation to each individual, depending on what stone he considers to be in these categories. It would seem, therefore, that we could more sharply define the words flint, chert, chalcedony, agate, jasper, quartz for a more descriptive reference to lithic materials and yet keep them in their proper categories. On Page _____ I have compiled a suggested outline of lithic materials under their workable categories and this may be of some help in material typeology. This represents a stoneworker's approach to selection of adaptable materials and will be further explained under individual material descrptions.

We could be guided by the Dana Handbook, but, again, this is controversial to some and so I think for the purpose of future description of lithic materials, we should use the "known" categories - without duplication - to cover tool-making materials. This I have tried to do in my outline.

When researching the stone-age tools, descriptions of artifacts generally made only a passing reference to material and, as a stoneworker, I was intensely interested in absolutely pin-pointing the material and relating it to the working techniques. This frustrating experience of searching, in vain, for any pertinent information on the relating of minerals to technques has led me to conclude that the student of lithic technology would be better informed and less confused if greater and more exacting reference were made to the materials from whch the artifacts are made and terms of reference could 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 sand-stone called quartsite, hornstone called flint, flint called chert, chert called flint, green jasper called bloodstone,etc.

When I talk in generalities 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". These terms cover all the suitable, workable stone as contained in the compiled outline. When talking to and comparing notes with other lithologists, 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. The aborigional, no doubt, had certain names for various minerals that were suitable for stone flaking and the terms "lithic materials","flint-like materials" and "silex " seem to be understood and acceptable to present-day tool-makers when they wish to include the entire field of workable stone.

I have further noted in personal conversation and correspondence with Bordes,Tixier and Titmus that we will often qualify our material by designating sources - such as "French flint" , "Gran Pressigny Flint","Swedish flint", "English flint", "Flintridge Ohio Flint","Danish Flint", "Oregon Obsidian", Idaho Ignumbrite", etc. This give immediate identification of material and conjurs up a quick mental picture of the minerals and the problems or bonus qualities contained therein.

Some European archaeologists have combined and grouped most of the working qualites 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. To me the words Silex and flint are synonomous, but I only make this reference when speaking of materials generally and not specifically.

The longer I examine the wide variety of rocks adaptable for making flaked stone tools, the more I realize that we must agree on a uniform classification of lithic materials. This would appear to impose a new burden on the profession, however, in the last decade, Archaeology has become increasingly more sophisticated and, because so many sciences are becoming a part of this study, it would appear that, ultimately, it must have categories of specialists - categories of typeology, lithology, flaking techniques, lithic materials, etc. to name a few related to the tool-making industry. This uniform classification should, to a degree, help in the study of lithic technology. It is hard to imagine that, in the future, a dedicated archaeologists could conscientiously apply his science and, at the same time, expand his energies to cover the related fields of anthropology, paleontology, geology, biology, zoology, botany, chemistry, necular physics, automation, mineralogy, and many, many other fields of research so necessary to complete the picture of this science. The implement types have a fairly uniform terminology in regard to form and, by further study of technology and materials, true sub-types of existant main types will very likely develop.

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 because his interest is in the isothropic properties of the given material. Even though there is a relationship to isothrophism and conchoidal fracture, the final results when testing depend on the surface and the conformation of the material. In other words, on the same block of good material a variety of flakes - flat, curved and of various dimentions - 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 chonchoidal fracture. To accomplish a breakdown of the varied minerals, one must approach lithic materials with the attitude of Ancient Man who was uninhibited in his analysis by his ignorance of our modern terms of Ignious, Metamorphic and Sedimentary.

The lithologists' first concern in choosing working material is quality of texture. The fineness or courseness of the micro-crystalline structure of the material when it was formed will determine the texture. Opal, obsidian and ignumbrites are exceptions. Opal is a hydrous silica gell with no apparent crystallography; while obsidian and ignumbrite are fused or welded glasses. The texture of the micro-crystalline varieties determines, to a degree, the toughness and tenacity of the material. The intertwining of the microcrystalline structure produces a fiberous character that resists the detachment of flakes by either pressure or percussion. The more coarsely textured materals 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.

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. The character of the stone is also important, i.e. bedding planes, inclusions, incipient cracks and internal stresses, etc. These will be discussed more fully in a later analysis of individual materials. But a stoneworker must be concerned with texture and character of material. While color and transparency will produce a more colorful and beautiful tool, they are not necessary properties of good lithic materials.

I would like to point out the differences in the multiple types of lithic materials. Each sourceof stone has certain attributes of which the worker is aware. For example, when Dr. Francois Bordes and the writer were doing some experimental flint working at the University of California in Berkeley, materials for our project were from many and diverse locations, i.e. Southern France, Northern France, Indiana, California ((2 locations), Oregon and Idaho, representing seven widely separated sources. After a week of working, the materials were almost entirely utalized and the resulting array of flakes were comingled in one big heap. Yet if any single flake had been given us - and this happened - we could identify its origin without error. The point I am trying to emphasise is that after working with a given material, the stone will reveal certain identifyable attributes that are characteristic to that material alone.

Other means of identifying good lithic materials are the texture and lustre and still other determining factors are the surface character such as the rind or cortex, the color, the transparency, the sound, the flexibility, sharpness of the removed flakes and last and probably most important is the amount of resistance to the necessary force required for detaching a flake.

The degree of lustre is used as a visual qualification by flakers to correlate the amount of force necessary to remove a flake of a given dimention. The variations of lustre range from glassy, waxy, greasy, satiny to dull, matt, flat, sugary, fine crystalline, medium crystalline, coarse crystalline and sandy. These are a few of the types of texture with each grading into the other. Lustre is one of the most useful attributes used by the lithologist in determining the workability of a given material. The refractive index of a material also has possible use in the degree of fineness or coarseness of lithic materials.

When hunting suitable material in the field, I find the most satisfactory method of testing is to drag your fingernail across a freshly flaked surface to denote its qualifications. If the fingernail moves easily across the surface, I can assume the material is finely-grained. If it hangs up or drags, then I presume the material to be coarse-grained. Most sources of lithic materials produce a material that is identifyable through special qualities recognized by the stoneworker. He must - when choosing material - determine the homogeneity of the mass and appraise the texture and lustre 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 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 bruising and listen to the sound of the tapping. If the stone gives off a dull sound, one can expect undetectable cracks, fissures and planes of weakness. However, if the stone has a sharp ring, the chances are good that the material will be of working quality. One may then remove a test-flake, or cleave the stone to examine it further. If this determines the material to be free of crystal pockets, foregin deposits and shows the right lustre, 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.

Some material is still available in certain alluvial deposits with new exposures. In 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. 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. 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 its usefulness to the stone flaker.

The multitude of cones are superimposed at random and intersecting 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 then is similar to what we laughingly call "goose bumps" or a multitude of little exposed cones. The recessed or concave protected areas often receive a polish from being burnished without shock against one another ~~without shock~~ AND DO NOT HAVE CONES. This cone-covered scarred surface is reminiscent of the surface of the moon. By ~~this~~ THESE types of surfaces, one is able to identify the cobble that has the desirable working properties.

Illustrate moon like Surface

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Illustrate moon like surface

As a source of material, surface finds are easier to secure than material which must be dug. However, since surface finds have recently been almost depleted by our present day "rockhounds" and it may take a million years for a new crop to weather out of its natural bed, we must dig. In the Western United States there are many tertiary deposits of extrusive volcanic rocks and it is in these rocks, under certain natural conditions, that hydrothermal deposits of silica compounds are deposited in the vesicules, cavities fissures, cracks and fault zones. These beds of decomposed lava are also much sought after by the rock collectors, as a great deal of the VESICULAR material FOUND IN THEM is considered as semi-precious gemstone. 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 aborigional stoneworker had uncanny ability in finding the best and most colorful quality 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 rarity, as the bubbles in the molten lave must have burst or rizen to the surface before the lave solidified. The sphere of sälicious material is a mold of the vesicule and,if found where it has weathered out, the surface of the sphere will be that of the mold and not like a water worn cobble. After one has been able to see a few specimans of each of these types of formations, it is easier to tell the difference. Occasionally, fissures and cracks will fill with agate, chalcedony and jasper and when they weather out they are in large tabular pieces idealy suited for the making of large bifacial tools. Some of the silex material deposited in the cracks and crevasses will form tabular pieces of usuable 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 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. The flakes discarded by the workman are then of more value in determining the location source of the material than the finished artifact.

The dorsal side of some of the flakes will show the natural surface of the material and this surface will show the natural cortex 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 a massive homogenous cryptocrystalline form, The type of crystallography is of utmost importance. The variety of crystallization will range from the amorphous opal to the massive quartz crystal. The hydro-thermal deposition and saturation of silica charged waters altered many of the normally unuseable 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. When I hunted for lithic materials, I looked for the flawless type of stone of adequate size that would have sufficient strength - one that would cleave in any direction - one without grain or clevage plane - and one that would break to a sharp edge under the application of percussion or pressure.

The variety of silica forms and combinations are endless. One may compare the resultant forms of silica in the earth's crust to a vast chemical laboratory filled with bottles of all the other mineral compounds and elements and then start breaking the containers at random to let them disfuse with a layer of silica compound on the floor of the laboratory - then subject this mess to heat, pressure, and the other conditions that produce stone. The results of such an imaginary experiment would, in part, replicate some of the natural phenomena that has taken place on the surface of the globe.

A few examples of this sort of impregnation of silica-charged waters are the fossilization of boggs and swamps, silts and sands. I might add that it may be of interest to note that some forms of silica have an affinity for organic material - possibly the same as 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 materials that I have used in my experiments to reproduce prehistoric tools are similar, or the same, as prehistoric stone-workers. 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 U.S. and abroad. This has given me the advantage of living in a sparsly populated area where lithic materials were fairly abundant, but I have had the disadvantage of not being able to study enough collections to permit viewing and comparing a larger array of materials used by the aborigionals. During the many years I have roamed the deserts in search of material, I always found, upon discovery of a source of good rock, that Ancient Man had been there before me and had quarried out the same material for their tools. Further it always seemed that the massive material they left behind I, too, discarded 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 problem for me since I first started my experiments. The first material 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, which will be discussed in detail in a later chapter. But, in the beginning, I only knew that I was attracted to their cast-off flakes because of the change in color, the shiny lustre 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 the thousands of years of prehistoric man working the deposits, I now have to contend with the present day hunters called "rockhounds". Because of these hobbists, there are now few remaining sources of good qualitymaterial of sufficient size to produce any large artifacts.

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 stone-knapper will always relate the quality of workmanship to the material.

Because of this close relationship of material and techniques, it is my opinion that we must conscientiously and qualifying appraise tools flaked from poor material with close reference to the material

Crude and Good Work

An example of determining crude work and good work can well be cited by a description of an excuvation on Brown's Bench in Idaho. Here a major excuvation was done by the professionals and the yielded results were a collection of thick, crudely-worked, random-flaked artifacts.

When the site was abandoned by the University, the amateurs began digging and pot-holeing beneath the University's excuvation. I visited the site and inspected the material the diggers were getting and found it to be beautifully worked, thin, well-controlled and

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When the site was abandoned by the University, the amateurs began digging and pot-holeing beneath the University's excuvation. I visited the site and inspected the material the diggers were getting and found it to be beautifully worked, thin, well-controlled and designed artifacts. Many collections contained not only projectile points but also

From a worker's point of view, these tools are among the finest and best designed of this technique and controlled points I have ever seen - yet they were made from the same material as the crude tools found by the University.

I could not be sure that the finely-worked points were, in reality, from a lower level, for they occurred in a

and the amateurs had disturbed the site to such an extent that it would be impossible to relate the finds to strategrophy. If they were from the lower level, it is conceivable that the older culture had an abundance of game and berries and, with full bellies, had time to fabricate a well-controlled point; whereas the late-comers may have found the "pickins" lean and, therefore, were so intent on keeping their larders full that hurried and sloppy work was necessary. This answer I leave to the archaeologists, but, in the considered opinion of a flintworker, here is a concrete example of good and poor work. Whether this was premidated, accidental, or because of lack of ability is a question the profession would have to ~~determine~~ answer, but certainly here we have evidence of ancient man using the same material, some resulting in crude work ~~and~~ with lack of control while others reflect sheer artistry.

used and not, too readily, assume they show "crude work". The 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.

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

KINDS OF MATERIAL

(1)

CRYSTALINE QUARTZ (SiO_2)

Rock Crystal
Quartzites
Sandstones, Conglomerates, Breccias
Bull quartz
Novaculite

(2)

CRYPTOCRYSTALINE QUARTZ (SiO_2)

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

Onyx
Sard
Sardonyx
Chrystoprase
Jasper
Bloodstone
Organic Replacements
- Casts
- Wood
- Bog
- Alge, etc.

2B Flint
Chert
Hornstone
Lydianstone
Touchstone

(3)

NON-CRYSTALINE QUARTZ (SiO_2) plus H_2O

Opal
Opalite
Silica Gels
Opalized Wood
- Bog
- Organic Replacements

(4)

IGNEOUS ROCKS

Obsidian
Pitch Stone
Ignimbrite
Basalt
Ryolite
Andesite
Felsite

(5)

SILICIOUS SEDIMENTARY

Welded Permiable Rocks
Silicified Sediments & Clays
Silicious Limestones

(6)

METAMORPHOSED ROCK

Slates
Fine Grained Porphyritic Rocks

(7)

EXOTICS

(8)

EXPERIMENTAL MATERIALS

Glass
Porcelain
Ice
Resin
Starch
Anthracite Coal
Coldtar
Gilsinite

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 the various lithic minerals useful, in different degrees, to the manufacture of stone tools. These descriptions will affiliate with the outline at the beginning of this chapter.

There are three main types of Quartz.

No. 1: Crystalline Quartz. The crystals detectible by eye.

No. 2: Cryptocrystalline Quartz. Quartz with hidden indistinguishable micro-crystals of the massive homogeneous variety.

No. 3: The non-crystalline Quartz.

These three groups are by far the most common used by both past and present stoneworkers.

No. 4: Ignious Rocks/ This group is not a part of the quartz family, but, when available, played an important part as a source of material.

No. 5: Silicious Sedimentaries. This group played a fairly important part as a source of material.

No. 6: The fine-grained metamorphosed rocks

No. 7: The Exotics. Materials of nebulous and unknown classification.

No. 8: Experimental materials. Materials used for student demonstrations.

Crystalline Quartz: 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 homogenity, 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 the 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 flaking them one can readily detach a flake and there is a marked difference in their workability. The type of quartzite that has been cemented by chalcedony joining the granules of quartz together is much better than the metamorphosed variety. There is also a difference if the material is formed of brecciated 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.

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 wheather 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 hammer-stone. 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 homogenity and texture then we have a material that is ideally suited for toolmaking.

Bull Quartz: This type of quartzite is the pegmatite variety usually found in the colors of snow white, opague and is some times stained with minerals. 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.

Novaculite: I have not had sufficient samples of novalulite to describe this material or fully describe 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. The samples I have are fairly course-textured and would fall in the category of good quality salicified sandstone. However, W. H. Holmes, in Bulletin 60, describes novaculite as being the same as cherts and chalcedonies with some having color. At the present time, I cannot attest to the workability of this material as my samples are not of sufficient size to determine the flaking qualities. Since the word Novaculite has been commonly used and accepted, I felt there should be some mention of it until a further study can be made to determine if it has qualities that will distinguish it from other materials.

Chalcedony: This form of silica is probably the purest form of the cryptocrystalline quartz family minerals. In its purest 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 bands 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 you might say 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 courseness of crystallization. The type with the finest micro-crystal structure has a waxy lustre and, after heating, the lustre is almost glassy. Possibly this variety contains more moisture for, when it is thermal treated, it requires more time and care curing the heating and cooling off period. It has a tendancy to craze and crack more easily 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 receiving the thermal 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 cryptocryatalline 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.

<u>Jasper:</u> Jasper is the result of a combination of chalcedony and argillaceous sediments or residual clays with a simultaneous absorption or infiltration of the two. Frequently the clays will shrink and leave cracks which will fill with chalcedony, giving the material the appearance of being fractured, but, actually, the cracks are well-healed with the chalcedony and a 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 chrystoprase is semi-translucent. Actually, green jasper is only an impure form of chrystoprase. Jasper may occur in various colors, the iron salts in their different valences producing green, red and yellow material and, occassionally, 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 to this rule - one is a course-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 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 worked this material very successfully. Another example of an unalterable is some local material called "Bruneau Jasper" from the ryolite 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 much used by the aborigional man in that area. The early man was able to alter this stone but, to date, 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 the past lithologists 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.

<u>Organic Replacements</u>: Organic replacements ar usually made up of members of the cryptocrystalline quartz family and have been much utalized for making flaked tool implements. Here, again, chalcedony plays the most important part as a replacement agent. In the 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, alge, bog material, shell, bone, etc. This material is usually quite distinctive because of the different species represented and can usually be identified by tracing their sources which would be more documentative than an analysis. ~~The cast of wood found in sedimentary rocks which~~

When wood casts, replaced by chalcedony, are found in sedimentary rocks they appear to be of a finer micro-crystallization 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 predominate 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 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 geographical distribution.

There are many paradoxical differences in flint that are not entirely understood even by the flintworker. Outwardly, or by visual inspection, one flint may appear to be 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!" Dr.Bordes did not say if this material was freshly mined or surface, but he did indicate 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 as to the definition - some define chert as an impure flint, while others maintain that flint is an impure chert. Others argue that chert and flint are the same. Again, there are those who believe that chert is pre-cambrian and flint is after chalk formation. Some use as a criteria the different degrees of transparency or translucency to determine which is flint and which is chert. Others use form as a defining criteria - maintaining that flint forms in nodules and chert in seams or blanket veins. Some base their decision on a color basis - declaring the dark colored material to be flint and the light colored to be chert. Even among stoneworkers there is disagreement, their criteria 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. Some have based the quality of flint 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 of 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 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 poor work on poor material. We must also keep in mind that there are those who do not recognize thermally treated material and they may be viewing this heated stone and calling in good flint whereas it could actually be an inferior stone improved by the thermal 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 - again, we have the old story of the chicken and the egg.

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 that 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 Gran Pressigny flint which was collected in 1937 by Dr. H.C. Shetrone and given to me in 1940 that 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.Boardes and Dr. Tixier sent me some fresh material from this same local 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 considering this 28 year-stored material to indicate that dehydration of flint is, indeed, a long and 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, Vol 7, Tebiwa. I heat the flint to 450 degrees F. for at least twenty-four hours. After that length of time the flint should have been dehydrated. The purpose of heating the flint is not to remove the moisture, but to aneal the stone by changing the crystallography, 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.

The 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" receiting their experiences and ideas on the stoneknapping techniques of Denmark. Because of the book, 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 absorbe 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, I might say that for our experiments at the University of California at Berkeley, Francois Bordes and myself received some Harrison County Indiana flint through the courtesy of Dr. Raymond S. Baby of the Ohio State Museum. This material had weather out of lime-stone 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 the pressure or percussion methods and we could see no reason to alter this material by using the thermal method. This material must be of considerable age, as it had apparently laid on the surface since it weather from the limestone. This would, therefore, seem to substantiate my theory that one must consider each individual material separately rather than judge its workability according to wheather it is freshly mined or surface - dehydrated or hydrated. The many locations of flint and other materials each have their 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 dimention. When one is making an appraisal of the formation of nodular flint, he will observe that the cortex is the surface of the nodule and that if it is insufficiently mineralized, or partly impregnated by the silica form of chalcedony, and is not a dehydrated flint, the cortex will be a combination of the silica and limestone, or silica and chalk, depending on what material the concretionary nodules of flint were formed in. The observer will note that, when a flint nodule is formed in a bed of limestone or chalk, upon cleaving, the center of the broken halves will usually contain a fragment of fossil organic material. Around this organic material micro-crystals of silica will form concentrically if the silica charged waters continue to permiate the deposit of chalk or limestone.

An example of this formation may be likened to the growth of a pearl in a shellfish by the depositing of nacreous material on a piece of irritating substances.

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.

In my examination of the cryptocrystalline quartz family rocks, 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 a semi-glassy, greasy finish much prized by the stoneworker.

Good quality flint has most of the attributes necessary for the making of most flaked tool implements. Working on flint produces a flake 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 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 infinity, while flint will break to the last micro-crystal, producing an edge with a dimunitive 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 the oapl 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, which is so useful to the stoneworker. The best definition is probably that found in Dana's"Quartz Family Minerals" - "Flint is nearly opague with a dull lustre and usually grey, smoky-brown, or brownish black. The exterior is often white from a misture of limestone or chalk in which it was originally imbedded. It breaks with a chonchoidal 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 purposes 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 synomous and the mineral constituants are dissimilar. A breakdown of the individual flint 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 cryptochrystalline varieties. of quartz.

I would like to suggest a possible method for determining the differences between chalk-flint and limestone-flint.that could be useful in an appraisal of the finished artifact when the material source in unknown. When flint forms in chalk beds it is a purer form of silica than flint formed in limestone. I base this statement on the fact that chalk is a combination of a type of silica known as chalcedony and the spicules and skeletons of diatoms - the skeletial remains of the diatomes being silica. Therefore, the combination of the two silicas carbonic acid - in association 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. Untill a more exhaustive study is done on materials, no conclusions may be drawn, but this may prove a need for further experiments.

<u>Opal - Non-Crystalline</u>: Group No. 3 is the non-crystalline varieties of quartz. It is in this group that we have precious opal, common opal, opalite, diatomite and the various replacements of organic materials. The chemical elements are a combination of silicon dioxide and water in variable amounts, Opal having 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 byroidal or stalictite masses or as a replaement of wood or other organic material. It varies widely in color and appearance and has a resinous or waxy lustre. The color of ppal may be white, yellow, brown, red, green, blue, grey, black or any combination of these colors. Opal is the most brittle of all the quartz family 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 arrowhead 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; fire opal - that with the quality of reflecting fire-like colors; girasol - translucent and blueish-white; common opal and semi-opal - that having many colors but without the fire-like reflections; cacholong - that which is opaque and porcelain white; opal-agate - opal of different color shades, sometimes banded; jaspopal - opaque because of the iron salts and other impurities; wood opal - opal silica replacing the substance and structure of wood; hyalite - a very pure form of opal associated with volcanic rocks and 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 high water 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 suddently 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 lustre 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 determing 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 fragil 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 flexibility 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 tendency 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 is found with the lustre of opal it is more likely to be of a heat-treated cryptocrystalline variety of quartz rather than that of opal or the non-crystalline type of quartz. 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 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 attached 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 for 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 tool-making as 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 no 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 feber 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 VirginaValley 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. Thefossolized bogs yield this type of opal in more massive beds by replacing the stems, roots, seeds and leaves of now extinct flora. These beds are now found in sedimentary deposits as blanket veins. Opal replacements are common where volcanic as has rapidly covered the organic material.

Opal, as a gemstone, has been recognized and acclaimed for some time. Most of the early material came from Hungary but, today, most of the precious opal comes from Australia. In the United States it has been found in Nevada and Idaho. I have examined the deposits in Idaho and Nevada and find they have one unusual quality that might be useful in determining their source. Most of the material - as well as the chalcedonies - from these deposits and to some extent in Utah has the property of floourescing yellowish green, indicating traces of uranium salts. How widespread uranium is I do not know, but, if it is restricted to these hree States, it would help pinpoint the sources of opal and agate. The opal probably contains a little higher content of uranium salts than the agate, and some of the opal has the property of phosphorescence - that is, after the black light is turned off, it will still glow in the dark. 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 material. In relation to 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.

Group No. 4 IGNEOUS ROCKS

Some varieties of igneous rocks are useful for making flaked stone tools, the most desirable of this group being:

1. Obsidian
2. Pitchstone, a courser grade of obsidian
3. Ignumbrite, 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.

No.1 Obsidian: A volcanic rock 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 it is sometimes red, brown, green and or variously striped or mottled in a combination of these colors. The striping usually is a result of the flow structure of the obsidian. Some obsidian has the quality of irridescence, exhibiting rainbow colors and other varieties have the quality of chatoyancy, showing a gold and silver sheen. Both irridescent 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 there 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 compensate 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 within the material with a radiating or spokelike 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 courser-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 phenomena in nature is evident in the obsidian found in pearlite beds. Often it is so brittle from internal stresses that one cannot remove the surface by grinding on a lapiday wheel without almost exploding the obsidian. Much of the pearlite 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. The length of time required for a change in composition is unknown. However, if and when, the sub-divisions of time were known of different obsidian deposits, tests could be made to determine the duration of time required for these changes to take place. Thee may also be a relationship to the surface material and that which is in situ. The difference in the strength of old or new obsidian may be only noticeable to the stoneworker. Gene Titmus, Henry Irwin and myself did some toolmaking work at the Blass Butte and Burns sites and became very 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 this difference in toughness and homogenity and allow for the difference in the force necessary to remove flakes of equal dimentions it is difficult to change from the Burns material to the Glass Butte obsidian.

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

Barney Reeves, University of Alberta and Leslie B. Davis of the Northern Montana College are doing research in the obsidian hydration procedure. Their conclusions should be a very important contribution to the Profession for dating and compiling sources of obsidian, and could be further useful in determining themigrational and trade routes of the aborigional peoples.

Obsidian requires a different working technique than the cryptocrystal ine 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 mo e 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.

No. 2 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.

No. 3 Ignumbrite: 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 he 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. The stone thus formed has an outward appearance of obsidian. Upon close examination of a fractured surface, ignumbrite 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. Ignumbrite 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. Ignumbrite 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. Ignumbrite 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 these ignumbrite cobbles can be worked.

When ignumbrite 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. Ignumbrite 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 re-constituted tuff.

No. 4 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 materials. When working basalt, a greater amount of control must be exercised to make pressure flakes of uniform dimentions 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.

No. 5 Rhyolite: Rhyolite is a light colored form of lave basically of the same composition as granite, but cooled more rapidly. The more rapidly cooled - the more vitreous its nature. The more vitrious 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 implements. 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.

No. 6 Andesites: Andesites, because of their great 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 is relative to the homogenity and texture of the andesite.

No. 7 Felsite;Y It is difficult to discriminate between rhyolites and andesites that are devoid of phenocrysts, making it necessary to use an elastic, noncommittal name. For the light-colored rock of this class, i.e. those which are light to medium grey, light pink to dark red, pale yellow to brown, purple or light green rather than dark green, dark brown or black, the term Felsite is convenient.

Rhyolite, andesite and feldsite are almost as difficult to define as the differences of 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 occurrance 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.

Group No. 5 SILICIOUS SEDIMENTARY

No. 1 Welded Permiable rocks: The impregnation of permiable rocks by silica (Chalcedony) can alter a semi-porous material 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 molecules are welded into one homogeneous mass. Rocks thus formed may be altered by the thermal treatment and are well suited for making stone implements.

No. 2 Silicified Sediments: The introduction of or the replacement by silica into types of sediments such as clays, silt and sand particles and indefinite mixtures and proportions may both fill up pores or voids and replace existing minerals. These silicious 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 tailus or in alluvial deposits. The silicious 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.

Silicified 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.

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

<u>No. 3 Silicious Limestones</u>: Limestones containing varaable 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 silicious 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 silicious skeletons of diatoms, thereby increasing the silica content.

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

No. 6 Metamorphosed Rock: Metamorphic rocks include all rocks which have formed in the solid state in response to pronounced ch 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 tool making.

No. 1 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.

<u>No. 2 Fine-grained porphyritic Rocks:</u> The metamorphosed, fine-grained pegmatites and 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.

<u>GROUP NO. 7 EXOTICS</u>

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.

<u>GROUP NO. 8 EXPERIMENTAL MATERIALS</u>

<u>No. 1 Glass :</u> 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 erailures, 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 more coarsely textured materials. Man-made glass has a uniformity and even consistency than 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 aboriginiss - 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 wth 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 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.

<u>No. 2 Porcelain:</u> 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.

No. 3 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.

No. 4 Resin: Resins may be used by students to practice pressing off flakes and to simulate small cores, etc. for determining the nature of fracture.

No. 5 StarbM: Starch has much the same character as resin and micro blades may be removed with the tip of a lead pencil.

<u>NO. 6, 7 and 8</u> Anthrasite coal, cold tar and Gilsinite 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 list of points and features may have some use at the present time and perhaps for even more extensive use in the future. It is not the purpose of the writer to burden the profession with an analysis of every scrap, discard and flake but only to point out some of the properties of lithic material that have significance to a stoneworker. This analysis is meant to create an interest in the material used by the Stone Age people and to project some of the features of lithic material that are so necessary to toolmaking. It is my hope that the scraps of stone found in campsites and on professional digs will take on more meaning than just a scrap of worked flint-like material and that these discards may some day help to complete the picture of the past.

A suggested list of points for appraising material are as follows;

1. Material. On page _____ is a compiled list of various kinds of lithic materials including some seven groups and sub-classes. The list is far from complete and includes only those materials with which I am familiar.

2. Mineral: Minerals are made up of many, many ites and the complete list and breakdown will have to be left to the qualified mineralogists.

3. Chemical Composition: This represents the porpotion, 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 as texture in degree, 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. Thecharacter 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 special 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 Occurance: Geological occurance can be useful when the material is found in place. Certain attributes, types of crystallization, textures, colors and qualities may be directly influenced by the geological nature in which it was formed. The finding of a deposit of usable material in place will do much towards a more accurate identification of a material in question than 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 one will moisten a thin flake, or a thick one broken to a sharp edge - then hold it towards a bright light, he will be able to see the degree of translucency as well as the mineral structure. The wetting of the surface is also good to bring out the true color of the reflected light and, at the same time, aid in revealing the structure which may be characteristic to that particular material. It is often difficult to determine the difference between ignumbrite and obsidian in the field but, upon holding a thin edge of a flake towards a bright light, the ignumbrite 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.

No. 10 Texture: Texture is the most important key to the workability of lithic materials as it indicates the degree of crystallization. Textures range from a 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 or percussion - the sharpness of the edges - and whether flakes of uniform dimention can be detached without the platforms or the flake collapsing. The finer the texture - the greater the control in making flakes, blades and tools.

No. 11 Edge Character: The edge character of a flake can denote how useful the material would be as a cutting implement, its degree of texture - the finer the texture, the sharper the flake. Tools made of the fine-textured material are useful for cutting soft materials such as leather, flesh, cordage, etc. The finer-textured material is 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. An illustration of the differences of a sharp edge and a coarse edge is the conversion of a cryptocrystalline quartz by the use of thermal treatment. For example: Agate in its natural state has an irregular edge - this irregularity the result of the size of the micro-crystals. In its natural state, it has much toughness well suited for drills, perforators, scrapers and other tools where it is unnecessary to remove long regular flakes and the edge need not be extremely sharp but rather 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 first altered by the use of the 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.

No. 12Resistance 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 one of the paradoxical things that are 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 materals 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 that receive the impact of the blow from collapsing. Flint has this quality, but it is not found in volcanic glass. 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.

No. 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.

No. 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 was not for this property of flexibility, there would be no convex or double-convex artifacts. Different materials have different degrees of flexibility. Heated cryptocrystalline minerals and volcanic glasses have this flexibility to a greater extent than the coarser-textured minerals.

It is difficult for one not familiar with stone working to fully understand this property, but a flint-knapper can control the flexing to an amazing degree.

No. 15 Cortex: This indicates 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 is used to identify the natural or unflaked surface of material useful for tool making. Examples are: the partly silicified surface or the incompletely mineralized exterior of nodules or masses of flint whether from chalk or limestone deposits. The bruised, abraided 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.

No. 16 Homogenity: 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.

No. 17 Heat Treatment: Whereby silicious materials are subjected to the controlled thermal treatment by man and are, therefore, artificially altered by man to change their original structure to one that will lend itself more favorable to the production of certain stone implements. This process will be described more fully in a seperate article.