PREHISTORIC USE OF QUARTZ CRYSTAL LITHIC MATERIAL IN THE CLEARWATER RIVER BASIN, NORTH CENTRAL IDAHO: A REPLICATIVE STUDY IN MANUFACTURE AND USE-WEAR ANALYSIS

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AUTHORIZATION TO SUBMIT THESIS

The thesis of Abram W. Grisham, submitted for the degree of Master of Arts with a major in Anthropology and titled, "PREHISTORIC USE OF QUARTZ CRYSTAL LITHIC MATERIAL IN THE CLEARWATER RIVER BASIN, NORTH CENTRAL IDAHO: A REPLICATIVE STUDY IN MANUFACTURE AND USE-WEAR ANALYSIS," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

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I must also give heartfelt gratitude to Dr. Don Tyler for his constructive criticism of this work and help in finalizing it.

Others that were not directly involved in development of this work but are of no less import in the development of this graduate student and deserve recognition include Dr. Rodney Frey, Dr. Leah Evans-Janke, Dave Quinn, William Mabbutt, and many others including friends and family unnamed here.

DEDICATION

This work is dedicated to my wife, Challis Grisham, for her invaluable support and belief in me. To my children Aisling, Brenna, Rowan, Lachlan, and Elin for adding fun to the chaos. Without their sacrifices this would have not been possible.

ABSTRACT

During prehistoric times quartz crystal was a valuable material for making tools and is found in Idaho's archaeological record. Due to the limited number of artifacts made from quartz, these tools have not received much archaeological analysis. The purpose of this thesis is to explore the use of quartz crystal tools that have been recorded in archaeological sites in North Central Idaho.

Quartz crystal is different than other raw lithic materials used by ancient peoples and a better understanding of the material, and why it may have been chosen by ancient peoples is necessary to help establish a more complete picture of the past. Sites from the Clearwater River Basin in North Central Idaho were selected to establish a regional picture of the distribution and frequency for quartz crystal. The region's rich quartz-bearing geology along with archaeological sites containing artifacts made from quartz crystal and unaltered crystals make this area appropriate for this analysis and research.

An overview of the geological aspects, physical properties, chemical properties and possibility of sourcing of quartz crystal gives background to this research. Even though quartz crystals occur in the region an evaluation of quartz crystals in 10 sites in the Clearwater River drainage was conducted showing that the frequency and tool type was very limited. Experimental manufacture and use-wear analysis was performed and showed that although difficult it is possible to make quartz crystal to produce usable and effective cutting tools and projectile points. The use-wear analysis shows that quartz crystal tools are durable and have regular and predictable edge wear. This information may be diagnostic in describing how quartz crystal tools from the archaeological record were used.

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CHAPTER 1: INTRODUCTION

In prehistoric times people of the Clearwater River Basin occasionally chose to use quartz crystal for lithic tool manufacture. Although the quantity of quartz found in the archaeological record is not significant enough to make up a substantial portion of the raw lithic material used, it does consistently appear to have been incorporated into the lives of ancient peoples across time and space. This poses compelling questions about the use and perception of quartz crystal by prehistoric people. Quartz crystal is by all accounts a rare geological occurrence, and highly prized in modern times for its collectability and use in industry. Was it also valuable and prized by prehistoric peoples of the Clearwater River Basin or was its use mostly utilitarian and expedient?

To establish the use of quartz crystal by prehistoric peoples the following sites were selected in North Central Idaho the following sites were taken from (Figure 1). Criteria for selection of the sites was established by two factors; evidence of quartz crystal in site collections and availability of quartz crystal as a raw material locally in the region. Discrimination was not selected for other site factors such as type of occupation, and site age. Thus all quartz crystal found within the ten sites was considered to establish use and distribution of quartz crystal.

It is my desire to use this study to perform an independent analysis of quartz crystal tool use-wear from raw stone found near sites of the Clearwater River that are part of this study. An analysis of this type will be beneficial to future archaeologists intending to examine quartz crystal tools in the region. I propose to do a use-wear analysis of quartz crystal tools of my own fabrication.

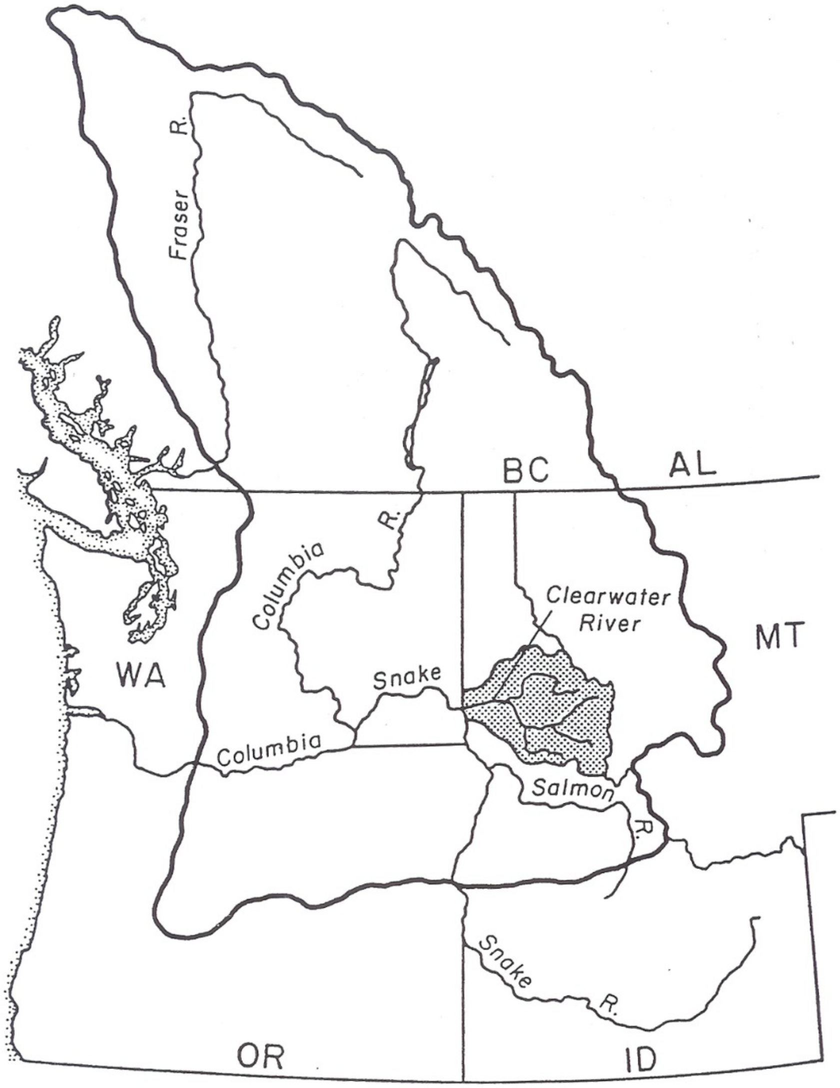

Figure 1. Clearwater River Basin Cultural Area shaded in grey.
Modified from: Sappington 1996

The methods used in the fabrication will mimic those of prehistoric peoples of the region. This replicative system analysis employs the use of experimental archaeology through lithic tool manufacture and use-wear to establish visible and measurable elements in analysis of past use of quartz crystal tools. This proposed analysis will enable archaeologists to examine quartz crystal tools and determine what their use was while still within the systemic context. Combined with Protein Residue Analysis, quartz crystal use-wear analysis can provide further insight into the purpose and past use of these types of artifacts.

Ethnographic accounts of the use of quartz crystal are limited at best and absent from the region. To my best knowledge no ethnographic research has been performed with tribes of the region, either *Nimipuu* (Nez Perce) or *Schitsu'umsh* (Coeur d'Alene) in regards to quartz crystal cultural importance, but evidence suggests that quartz crystal material may have been highly esteemed among ancient peoples (Whitley et al. 1999) (Kohntopp 2010). Other sites containing quartz crystal artifacts will be discussed briefly to augment theories of quartz crystal artifact value. Those accounts are discussed later in the Cultural Considerations section of this text.

The intent of this work is to explore why prehistoric people used and collected quartz crystal. This can be accomplished to some degree through quantitative analysis, use-wear analysis and tool fabrication and qualitative analysis, and examining cultural or ethnographic use of quartz crystal in specific contexts from other regions.

Research Questions

Archaeological excavations conducted in the Clearwater River Basin have established the existence of quartz crystal in site occupations. The use of quartz crystal by prehistoric peoples poses the following questions for researchers and archaeologists:

1. What are the geological properties of quartz crystals, chemically, physically, and molecularly?

2. What is the occurrence of quartz crystal in the Clearwater River Basin and are there methods sufficient to discriminate sourcing of quartz crystal prehistoric quarries?

3. What insight can be gained from the occurrence of quartz crystal in regional archaeological sites?

4. Can experimental manufacture of quartz crystal lithic tools give insight into any prehistoric people’s use of quartz crystal?

5. Can a replicative systems analysis be performed on quartz crystal tools to establish use-wear patterns for analysis, and can this use-wear analysis be effective in identifying use-wear of prehistoric tools?

6. Are there any cultural and ethnographic considerations that might indicate prehistoric people’s propensity to procure and use quartz crystal from their environment?

CHAPTER 2: QUARTZ CRYSTAL

Introduction

Quartz crystal is a unique formation of naturally occurring silica. Silica, the second-most common element in the earth's composition, comes in many different forms and quartz crystal is one of the rarest physical presentations. Pure water-clear and colored crystal are cut and used in many capacities from jewelry to electronic engineering, from window glass to concrete. No other species of mineral compares in diversity of varieties and in use to man both in prehistorically and historically humans have relied on this diverse mineral to solve a plethora of technological problems. Flint, a form of quartz, helped prehistoric humans effectively harness the use of fire for warmth and cooking, extending the northern range which they were able to occupy (Hurlbut 1970). The focus of this research is limited to the use of quartz crystal as a raw lithic material selected to make lithic tools. These tools are limited in location to the Clearwater River Basin of Idaho.

Chemical and Physical Properties of Quartz

Quartz is a simple chemical compound made from two common elements, silicon and oxygen. The chemical formula of quartz, SiO_2, is made up of one silicon molecule bonded between two oxygen molecules. Many variations of molecular arrangements exist depending on heat and pressure during formation. High temperature and pressure during megaquartz crystal growth result in an arrangement of a tetrahedron composed of SiO_4 (Fig 2). This structure is chemically inert and very stable at room temperature.

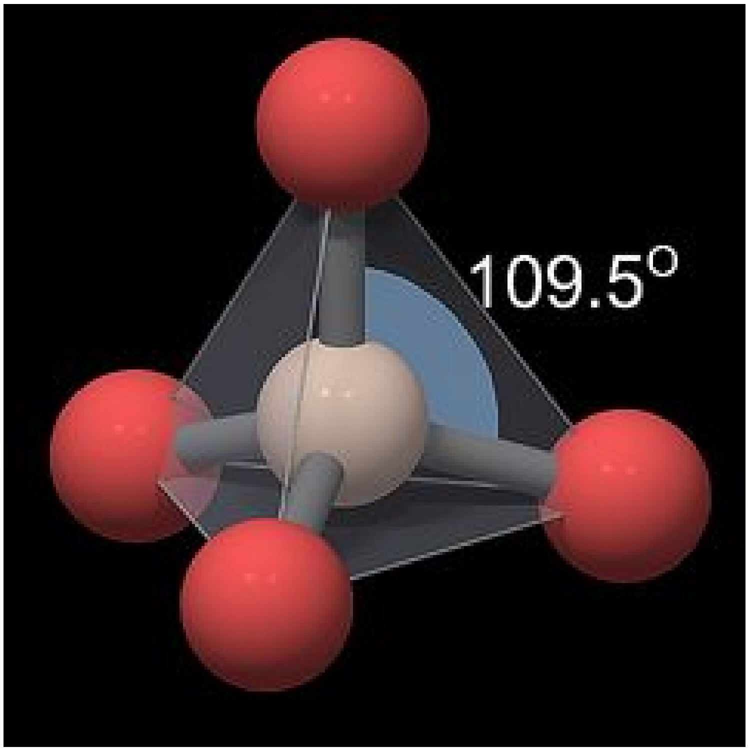

Figure 2. Quartz crystal tetrahedron molecular structure. Silica molecules are represented by white and oxygen in red. The angle of the bond is 109.5 degrees.
Used from: http://www.quartzpage.de/gen_chem.html 2015

Tetrahedrons are bonded together at the axis and the Si-O-Si bond linking one tetrahedron to another is not straight, but an oblique angle of 144˚ (Figure 3). Different types of quartz have varying angles of tetrahedral bonding dependent on the formation process. All forms of quartz maintain the same central tetrahedron angles of 109.5˚, but because tetrahedron to tetrahedron bonding can vary, crystal structures can be complex. This must be taken into consideration when choosing quartz as a lithic tool raw material. Because of the complex structure the material does not always fracture in a consistent and predictable way making analysis difficult (Driscoll 2011; Tallavaara et al. 2010).

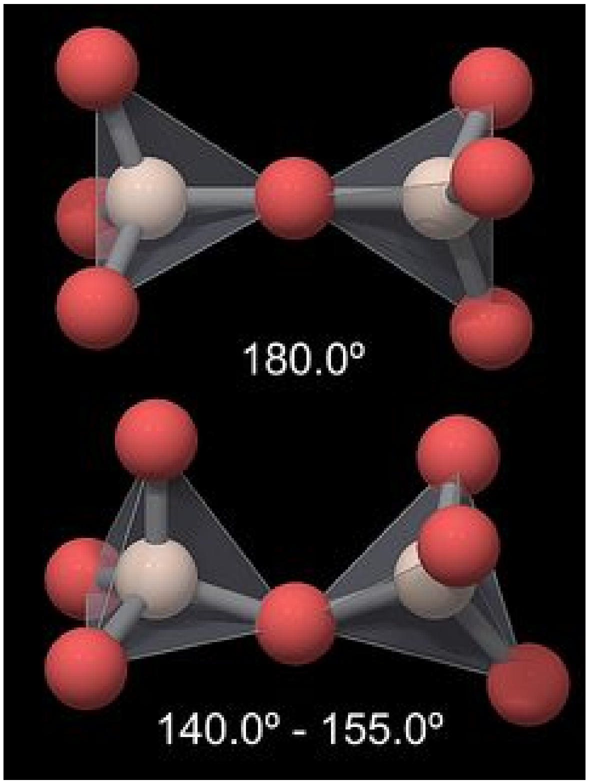

Figure 3. Tetrahedron to tetrahedron bonds vary from 140.0˚-155.0˚ as shown in the lower illustration. Bonds of 180.0˚ as in the upper illustration do not exist.
Used from: http://www.quartzpage.de/gen_chem.html 2015

Quartz molecules are composed of covalent bonds. In covalent bonds, electrons are shared between atoms, unlike ionic bonding where electrons are transferred from one element to another, and held together through electrostatic attraction. Ionic bonds can become unstable when in contact with a solution such as water. An example of this is Sodium Chloride, or common table salt. When it contacts water, the ionic bonds are broken and the elements dissolve into solution. Quartz does not have ionic bonds but rather covalent bonds, so electron structure in the bonds are very stable in solution. As a result quartz is almost completely inert when submerged in water at room temperature (Quartzpage 2014).

Quartz comes in many varieties. Principally there are two forms of quartz resulting from differing varieties of silica compounds (Roberts et al. 1990). The most iconic form of quartz is the six-sided megaquartz crystal. The external appearance and internal opacity give it a high desirability and collectability. This type of quartz again is the main concern of this research, but the chart also shows the other forms of quartz to offer the reader an explanation of differing quartz materials found in lithic assemblages.

Six-sided quartz crystals were first described in scientific literature in 1672 by Robert Boyle who after studying their properties considered them to be ice frozen so hard it could not be melted (Hurlbut 1970). After measuring the specific gravity he concluded that the crystals were formed through crystallization of water. This postulation was partly correct as crystals do form from solution growing to form a matrix of silica but as we know now the minerals are not frozen water but deposits of silica and oxygen. Discussion of the formation process will be given attention later in this work, but the physical properties and shape of quartz crystals are the principle reasons of which it has been used in lithic tool manufacture.

Quartz crystals ordinarily grow in hexagonal bars, ending in a pyramid like termination. The first studies of quartz crystal determined through precise measurements that the angles of the crystal’s face do not vary, and the ends of the pyramid terminations occur on both vertices of the bar. Also observed was that the crystal faces were not equal in size but rather one side of the crystal will have larger faces than the other (Ribbe 1990). The common way of labeling a crystal is by it being right-hand or left-hand faced. Interestingly in nature about the same number of right-hand and left-hand crystals are formed so there seems to be no natural preference to how a crystal grows. Figure 4 shows illustrations of left and right faced crystals, and how to determine a crystal’s facing formation (Ribbe 1990).

Quartz Types	**Visual Characteristics**	Luster
Megaquartz		
Rock Crystal	Clear	High
Rose	Pink to red	High
Smoky	Brown to black	High
Amethyst	Violet and purple	High
Citrine	Yellow to reddish brown	High
Milky	Milky to grey white	High
Rutilated Quartz	Contains acicular rutile inclusions	High
Aventurine	Contains micaceous or hematite inclusions	High
Ferruginous	Brown and red with inclusions	High
Microquartz (Cryptocrystalline)		
Chalcedony	White to blue and black, with waxy luster	Waxy
Agate	Banded chalcedony	Waxy
Jasper	Red from iron oxide	Silky
Onyx	Banded agate with parallel lines	Silky
Moss Agate	Agate containing dendritic inclusions	Waxy
Sard	Brown translucent chalcedony	Silky
Carnelian	Red to reddish brown translucent chalcedony	Dull to waxy
Chrysoprase	Apple green translucent chalcedony	Waxy
Plasma	Green opaque chalcedony	Vitreous
Prase	Leek green translucent chalcedony	Waxy
Heliotrope	Green with red spots of iron oxide	Vitreous
Bloodstone	Mostly iron oxide red with green	Vitreous
Flint	Brown and blue to white. compact microcrystalline	Waxy
Chert	Color varies grey to brown, green and red. compact microcrystalline	Vitreous to waxy
Novaculite	White to grey and black, used for wet stones	Dull to waxy
Tiger Eye	Yellow, brown and green banding	High

Table 1. Quartz varieties with visual and surface characteristics. Created from Roberts et al. 1990.

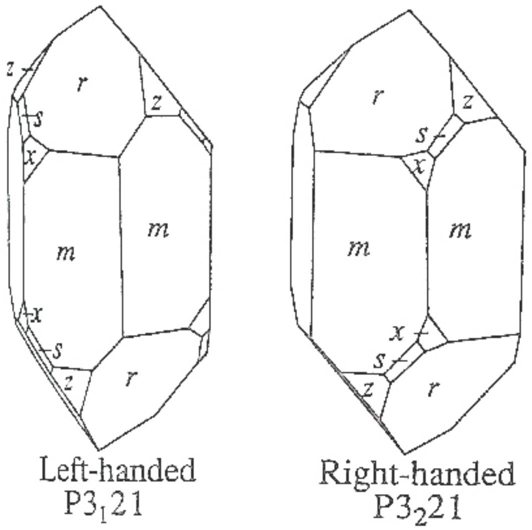

Figure 4. Crystal facets determine whether a crystal is right-handed or left-handed in crystal facing (Ribbe 1990).

Quartz crystals have unique light transmission properties and refracting qualities. Rotary polarization is a phenomenon in which the polarizing plane of light is refracted one direction or another. Light passing through a quartz crystal is rotated on the plane of polarization to the side of which the crystal is faced. Other naturally occurring crystals also have this property but none so pronounced as quartz (Ribbe 1990).

The common radio transmitter is operated through the use of quartz crystal due to a material property called piezoelectricity. Piezoelectricity is created when an electrical pulse is run through a quartz crystal, due to the conductivity of the quartz material the electric pulse is deflected at a constant rate. By orienting the crystal grain and by differing thickness the electrical pulse is stabilized and controlled through deflection. This control allows radio frequencies to be tuned or stabilized into specific wave patterns (Ribbe 1990). Quartz crystal is useful in this regard due to its highly pure molecular formation of silica and oxygen, with crystals having impurities less than 1: billion. Its uses in today's electronic manufacturing are too many to number but it can be found in computers and watches just to name two of the most common.

Quartz is chemically simple, composed of SiO_2 with a silicone to oxygen ratio of 1:2. This ratio makes up the tiny molecular building units of quartz. The molecules are arranged so that each silicon molecule is surrounded by four oxygen molecules creating a tetrahedron. At the corners of the tetrahedral bond each corner oxygen is shared by two silicon molecules. In quartz crystals these tetrahedral groups are arranged into spirals that run the long axis of the crystal bar, if the spiral runs to the left, the plane of polarization will also run to the left, and vice-versa. This is ultimately the structure and chemical composition of quartz on a molecular level, but quartz has many variations in composition and conditions of crystallization produce variations in crystalline properties of each form.

Quartz is rated (H=7) on the Moe's hardness scale making it very hard and is easy to identify by a scratch test. It has a specific gravity of 2.65 making it average for nonmetallic minerals, but unlike most minerals it has no cleavage but rather has conchoidal fracturing similar to glass or obsidian (Whittaker 1994). The fact that it has conchoidal fracturing properties make is the reason prehistoric flint-knappers would have chosen the material for lithic manufacture, because it would make sharp edges for cutting (Whittaker 1994).

Impurities at the molecular level create varying colors in crystals. Amethyst, citrine, rose and smoky are a few of the common color variations found. Although these impurities occur in varying amounts, chemical analysis of colored quartz structure shows that the crystals still approach the purest form of silicon dioxide (Hurlbut 1970).

Quartz can be discriminated into two categories, quartz α and quartz ß. Quartz ß will not be considered in this work because it is only stable in crystalline form at temperatures between 573˚ and 870˚ C. When found in raw form quartz ß is brittle and cracked, making it unfit for lithic tools (Ribbe 1990).

Quartz α can be divided into two categories, either fine or coarse grained crystalline structures (Ribbe 1990). The two differing variations are identified as megaquartz and microquartz respectively. Megaquartz crystalline physical properties are identified with large, fully formed hexagonal rod structures. Megaquartz coarse grain crystals have visible facets of large structure and this study is limited to raw material large enough for lithic tool manufacture. Microquartz is all other species of quartz which have small crystalline structure which include chalcedony, agate, jasper, onyx, moss agate, sard, carnelian, chrysoprase, plasma, prase, heliotrope, bloodstone, flint, chert, novaculite, and tiger eye. Many archaeologist designate tools of microcrystalline structure as cryptocrystalline (Table 1) (Ribbe 1990).

For centuries megaquartz crystals were referred to as "rock crystal" but now the word crystal, taken from the Greek word "*cristallos*" meaning water, is used to identify all minerals with structures having crystalline external shapes (Hurlbut 1970). This is not limited to quartz crystal (SiO_2), for example in other minerals like garnet $X_3Y_2(SiO_4)_3$ or emerald ($Be_3Al_2(SiO_3)_6$) structural formations are also called "crystals" due to their faceted shape, even though they have different molecular compounds than quartz. Some confusion can arise when the term "crystal" is used to describe megaquartz formation, because crystal describes the faceted shape of the mineral, not its chemical composition.

Large megaquartz crystalline structures are rare when compared with the vast amounts of material that forms as microquartz crystals. Microquartz formations occur all over the world making up a large portion of the earth's crust. Small crystals of microquartz grow very tightly together and form the bed rocks of granitic geomorphological formations. These small crystals are liberated from their matrix through erosion and overtime washed down streams and rivers into the oceans. These silica sand crystals are what make up most of the world's beaches, settling into large deposits in oceans and lake beds, overtime becoming compacted to make sandstone (Hurlbut 1970).

Fine-grained varieties of quartz do not contain any external evidence of crystalline structure. Although physically different than their coarse crystal counterparts, fine grained quartz are chemically identical. Fine grained quartz indeed have crystalline structure and under magnification can be easily identified even though the crystals are very small and grow completely together to create a homogenous texture (Ribbe 1990).

There are two types of microquartz crystalline structures, designated as granular types and fibrous types. Granular types of microquartz receive no special designation but are simply microcrystal forms of megaquartz. A vein of quartz running through matrix is an example of a granular microquartz (Ribbe 1990). Fibrous types are generally known as chalcedony. A limited description of the properties of chalcedony is necessary to this research for the purpose of discrimination between pure quartz crystals (coarse-grained) and chalcedony (fibrous). Chalcedony occurs mostly in basalt and rhyolitic flows with open spaces where the material is transported in hydrothermic solution into open cavities filling the vacuous spaces called vugs. Carnelian, agate, opal, onyx, chrysophase, flint, chert, and jasper are all variations of fibrous microquartz formations. All fibrous quartz varieties are formed through hydrothermic solution infiltration processes (Ribbe 1990).

One of the unique physical properties of quartz is its ability to luminesce. This phenomenon called tribo-luminescence is created when the chemical bonds of a material are broken through abrasion. Electrical energy is released and light is produced that can be seen (Whitley et al. 1999).

Formation of Quartz Crystals

Quartz and its many varieties are second only to feldspar in abundance in geological formations on planet earth (Stoll 1950). Silica, the basic building block of quartz, is the same basic molecule in most knappable stone materials. For example, obsidian, which was used in great quantity throughout Western North America is also made of silica (Whittaker 1994). The defining feature that sets quartz crystal apart from other silicates is the way that it is formed geologically.

Pegmatites are voids in bedrock where the formation of megaquartz crystal happens (Figure 5) and two types of pegmatites exist, igneous and metamorphic. Igneous pegmatites are formed from residual volatiles of the magma itself, while metamorphic pegmatites are formed from mobile mineral constituents that concentrate during metamorphic differentiation (isu.edu 2014). The term pegmatite will be used here to refer to both igneous pegmatites and metamorphic pegmatites; no discrimination will be needed as both produce megaquartz crystals.

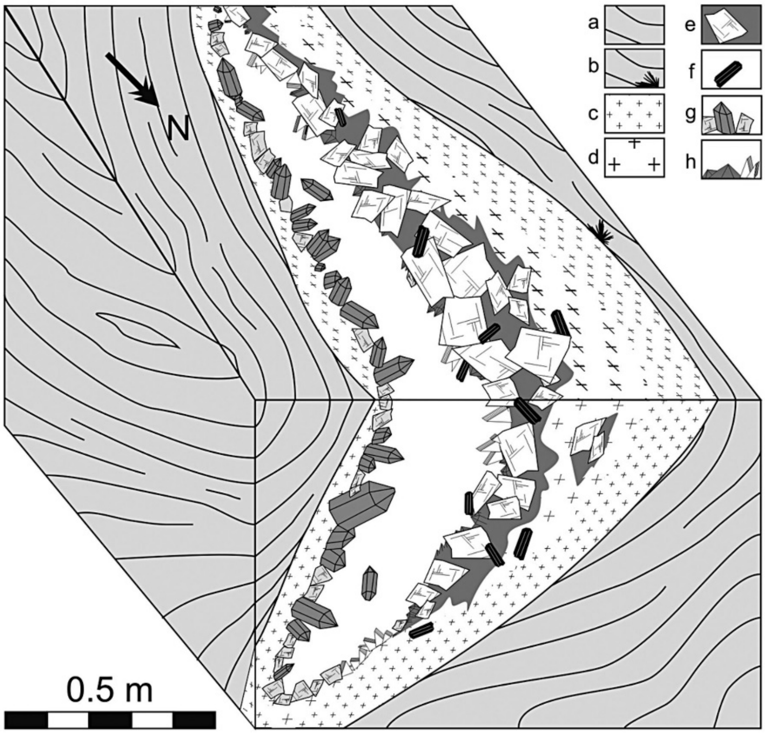

Figure 5. Illustration of a pegmatite gaseous void filled with crystals.
Used from: http://www.canmin.org/content/50/4/895.abstract 2014

Pegmatites are found near or on plate tectonic subductions zones (Figure 6). These zones occur where one continental plate is being driven under another, as is found on the west coast of North America. These plate collisions result in molten plutons or magma pools that flow towards the surface. If the magma reaches the surface, volcanic flows turn to lava that cools into basalt and sometimes to obsidian. But if the magma is trapped underground, pegmatites will form at the upper most part of the pluton (Figure 7) (isu.edu 2014). Under immense heat and pressure, silica precipitates out of the magma and or the bedrock and mega crystals form (Stoll 1950). On occasion the crystals can reach large sizes up to meters in length, but large-sized crystals are not common (Hurlbut 1970).

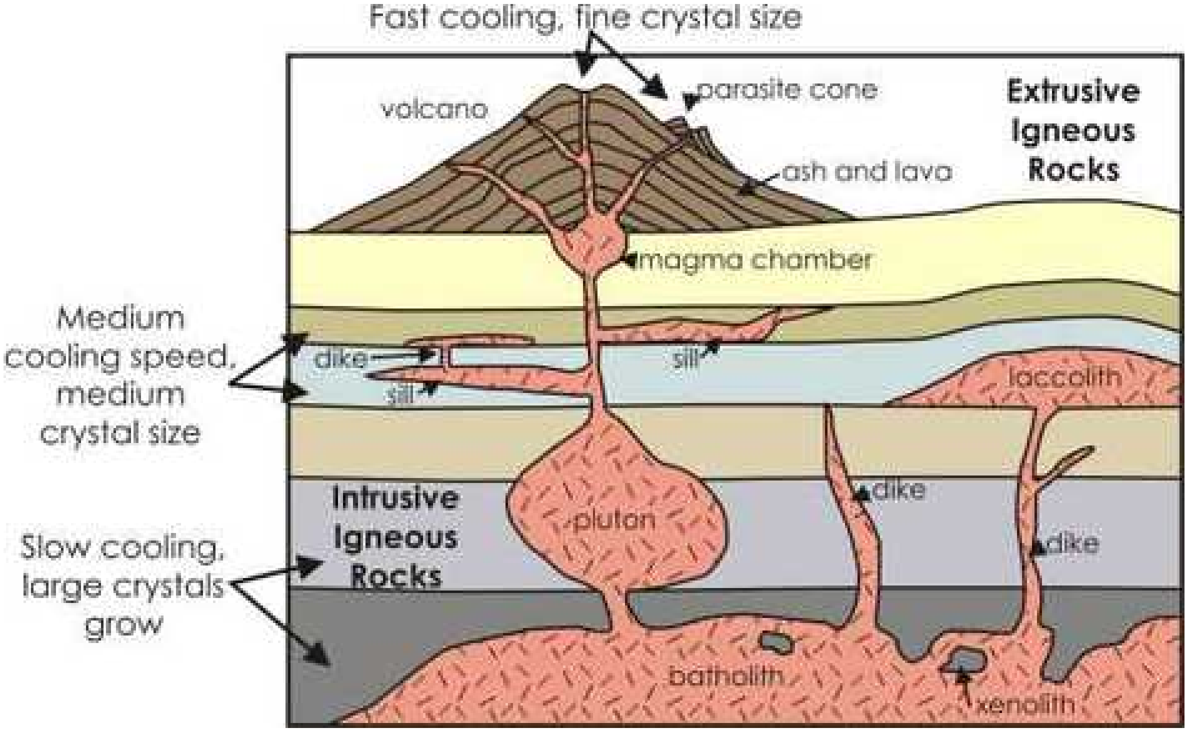

Figure 6. Cross section of a subduction zone showing locations of crystal growth.
Used from: http://landonellis.weebly.com/1/post/2010/12/the-geology-of-national-parks-yosemite.html 2014.

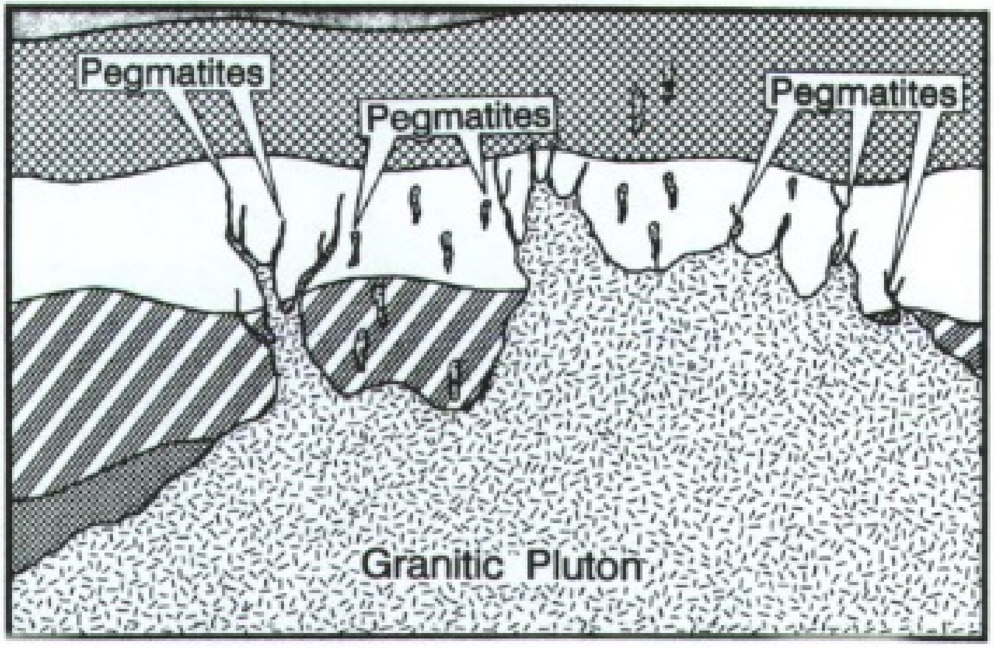

Figure 7. Close up of pegmatites near a large pluton.
Used from: http://www3.northern.edu/natsource/EARTH/Rosequ1.htm 2014.

High temperature and pressure near plutons deep in the earth’s crust drive water towards the surface precipitating out minerals as it travels. Reaching cooler locations and lower pressure the minerals begin to drop out of solution in hydrothermal deposits. Water is supplied by the magma which can be as much as 8% water by volume (isu.edu 2014).

Pegmatite mineralogy tends to be simple but mafic pegmatites (containing magnesium and iron) are known to occur even in Idaho (isu.edu 2014). Typical mineral composition is quartz, orthoclase feldspar and mica, and some may contain small garnet and tourmaline as disseminated crystals. Other common minerals such as chalcopyrite, molybdenite, sphalerite, beryl, apatite, tourmaline, monazite, topaz, spodumene, cassiterite, and lepidolite also form in pegmatites. Rare minerals can also form in pegmatite such as thorium, uranium, tantalum, niobium, beryllium, lithium, cesium, and cerium (isu.edu 2014).

Pegmatites typically have layers of crude zoning. Quartz is one of the last minerals to crystallize in pegmatite formations resulting in a quartz center (isu.edu 2014). The outer crust of pegmatite formations tend to be where other mineral formations can be found. Like a geode, minerals crystallize from the outside towards the center (isu.edu 2014) and if there is sufficient space and the crystal growth ceases before the gaseous center is filled. If the void fills in completely with crystal growth then a quartz matrix will result with no separation between crystalline forms. Thunder eggs are a good example of this type of pegmatite formation (Stoll 1950). Gas cavities can range from inches to feet and diverse gem minerals can be found inside the pegmatite gas cavities. One reported pegmatite found on the Idaho-Montana border is the size of a railroad car (Mabbut Personal Communication 2014). Within these hollows in the bedrock, crystals slowly take shape. Idaho boasts many areas of pegmatites filled with large-faceted crystals of amazonite, aquamarine, topaz, smoky and rose quartz, and corundum (isu.edu 2014).

Idaho’s central mountains are part of the Idaho Batholith, a large uplift of igneous granite that millions of years ago rested over the Pacific Rim subduction zone. Subterranean plutons were common throughout the batholith. Many of these underground pools of magma formed megaquartz crystals as they slowly cooled in pegmatite voids. The result is that pure quartz crystals are found throughout Idaho’s central mountains (Stoll 1950).

Pegmatites become exposed only through erosion. By examining the float of an eroding rock slope it is possible to find exposed pegmatites. These pockets or cavities in the bedrock may contain large fully-faceted crystals. Large pieces of feldspar and mica are also indicative of pegmatite formations in an area. If any type of crystals are found then without doubt there existed a pegmatite formation. Pegmatites can also be located by looking for areas of vegetation on the exposed faces of rock. The outer edges of pegmatites weather faster than the surrounding bedrock and subsequently when exposed will collect water, leaving a rain catch for moss or other plants to thrive on (Mabbutt Personal Communication 2014). Quartz, being extremely hard, will weather slower than the matrix surrounding it, leaving the crystals exposed. If one pegmatite is located it is probable that there are more of them close by because pegmatites occur in groups (isu.edu 2014).

For mineralization to take place bedrock must possess certain attributes; the rock must have high permeability and high porosity. Hydrothermal transport of minerals can be achieved in bedrock of high silica content by faulting. Silica fractures cleanly with little or no dust, leaving cracks where fluid may travel efficiently through rock layers. Other types of permeable rocks are sandstones and metamorphic conglomerates where space between granules is minimal and size is consistent. Igneous beds such as basalt and rhyolite tend to have joints, fractures and vesicular formations allowing solutions to easily pass between layers. Bedrock that is porous but low in permeability such as shale or clay will block the hydrothermal transfer of minerals including silica (isu.edu 2014). This is due to the rock's ability to absorb the hydrothermal solution but not allow it to continue towards the surface. In areas of shale and clay beds many times a quartz layer will form directly under the impermeable layer, and be thin and brittle with no space for development.

Fault zones tend to have high hydrothermal mineral permeability. But shear zones (highly-fractured zones with subparallel fault planes) with a high degree of shatter and gouge (finely ground rock) have reduced permeability. Subsequently, the most favorable locations for hydrothermal mineral transport and deposition occurs where the bedrock has small faults with slight displacement. Typical favorable fault configurations include subparallel groups of faults, intersecting faults, fault branches, and stockworks (a zone of intersecting faults characteristic of cylindrical shape) (isu.edu 2014). Figure 8 is an illustrative example of hydrothermic solution intrusion into a fractured fault zone.

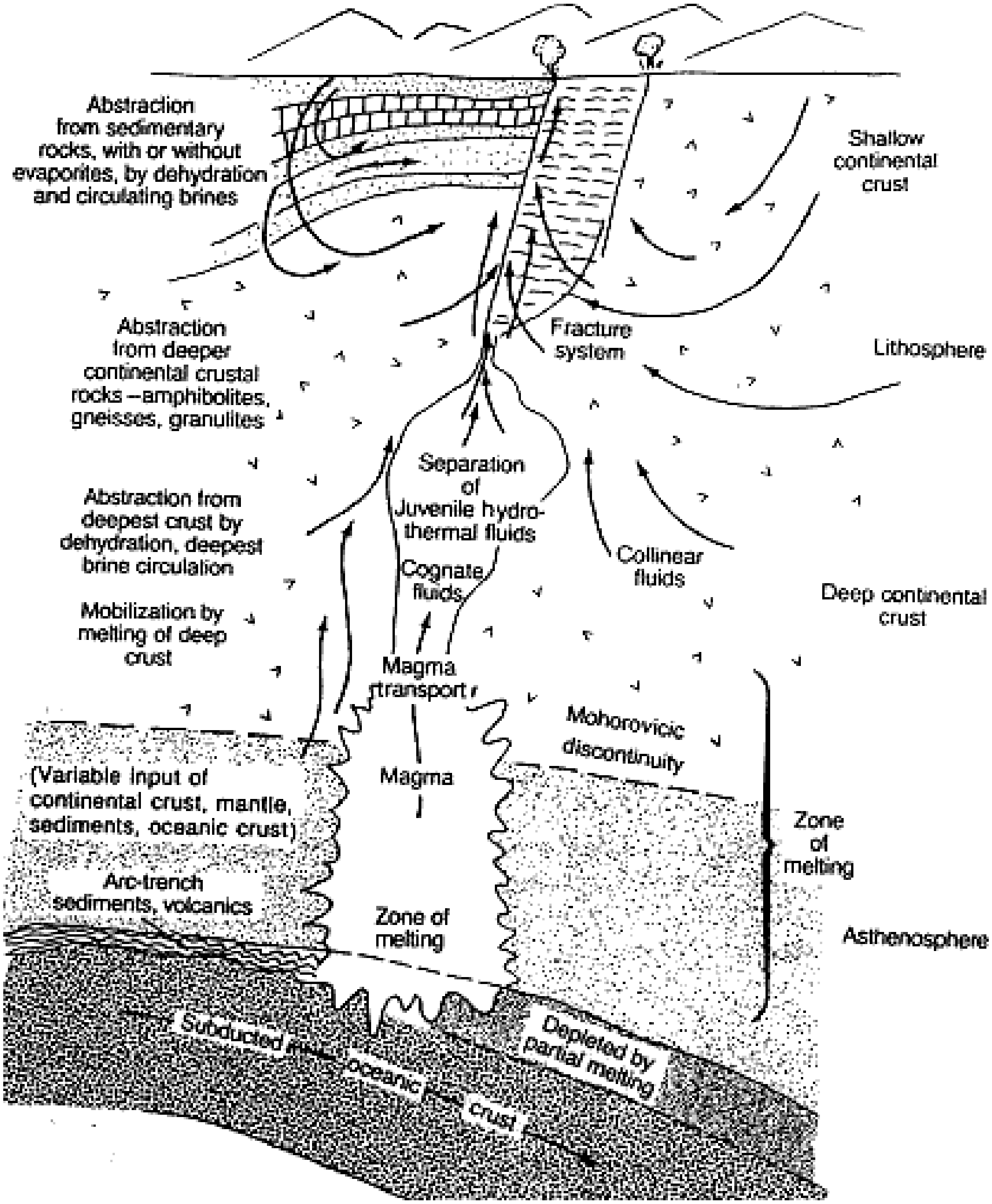

Figure 8. Illustration of fault zones that transport hydrothermic solutions through bedrock. Used from: http://imnh.isu.edu/digitalatlas/geog/mining/minefr.htm 2015.

Sourcing Quartz Crystal

Quartz crystal proves difficult to source. Pure quartz crystals grow from a single crystal seed and tend to be extremely pure in composition with few if any inclusions (Stoll 1950). This lack of trace elements in megaquartz results in stones without identifiable chemical signatures (Bruggencate et al. 2013).

Improvements in the quality of geochemical equipment have occurred in recent decades, but sourcing megaquartz still requires multiple methods to create better reliability (Bruggencate et al. 2013). As stated previously pure quartz crystals grow from a single crystal seed and tend to be extremely pure in composition with few if any inclusions. This is very different from other silicates like obsidian which have trace elements such as magnesium and iron that are in readily identifiable quantities. The combination of elements in obsidian creates a consistent chemical signature that can be identified by the means of X-Ray Fluorescence or XRF (Whittaker 1990). Once a source's chemical signature has been identified any artifact can be tested through XRF to match that source signature. The reliability of XRF chemical analysis on obsidian has proven to be very good and made it the most popular way of sourcing obsidian artifacts (Sappington Personal Communication 2014).

Quartz crystal does not work with XRF due to its high purity. This purity has been problematic for archaeologists attempting to locate sources of workable crystal tool stone. Without source information we cannot create models of trade and transport of material across time and space (Bruggencate et al. 2013).

Archaeologists have had to rely heavily on visual analysis for sourcing quartz crystal materials in the past (Bruggencate et al. 2013). This is problematic in two ways; first, visual analysis can be subjective depending on the opinion of the analyzer and second, many sources of cryptocrystalline quartz are so alike in appearance, that it becomes impossible to differentiate between two similar looking sources (Bruggencate et al. 2013). As a method for sourcing, visual analysis is not conclusive enough by itself to produce consistent results when working with pure quartz crystal tools. Bruggencate et al. in 2013 proposed that a combined visual-geochemical analysis would be a more effective way to source cryptocrystalline and quartz artifacts. The following are methods of this proposal, which includes both effective and ineffective methods. Figure 9 is an example of visual analysis in quartz crystal artifacts. The parent crystal of the image shows small inclusions of pyrite crystals, these inclusions are rarely found in pure quartz crystals so if lithic tools are found close to the source pegmatite containing the same inclusions it can be evidence of the material source (Mabbutt Personal Communication 2015).

Oxygen Isotope Characterization has proven to be reliable for establishing geochemical signature in quartz formations but tends to only result in broad geographical results. Geologists have used this technique extensively when identifying sources of materials associated with large geomorphological formations. This technique can be useful to archaeologists in establishing what geological formation materials came from but alone is insufficient to pinpoint specific quarry sites (Bruggencate et al. 2013).

Thermoluminescence dating can be used to identify trace elements in quartz materials. Although it doesn’t create a quantifiable data set of trace elements found in quartz material it does help to identify which if any trace elements exist. As a sourcing technique it has been effective at analyzing quartz crystals to distinguish potential chemical differences in quartz assemblages, but again alone is not sufficient to pinpoint quarry sites (Bruggencate et al. 2013). Also the process is destructive to artifacts and considering that quartz crystal tools are rare some archaeologists may be less inclined to its use as a geochemical identifier.

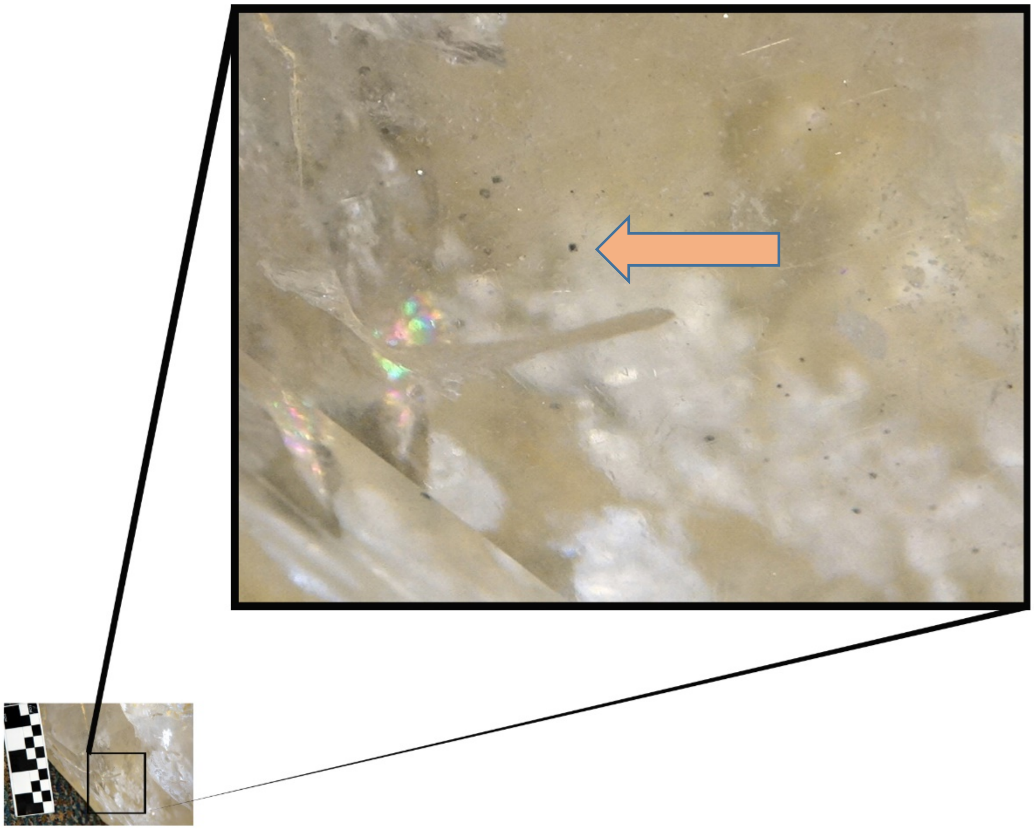

Figure 9. A close up photo showing pyrite inclusions in a large quartz crystal identified by the arrow. Inclusions such as pyrite can be diagnostic in sourcing quartz crystal material.

Trace Element Analysis has proven to be ineffective in identification of lithic material sourcing due to the purity of quartz crystal chemical composition. Quartz crystals are formed of tightly woven spirals of an interlocking silica-oxygen tetrahedral. The molecular bonds of the tetrahedral are of a size and valence that very few other trace elements are able replace the silica-oxide composition. This reduces significantly the trace elements that might be found in the crystalline forms to levels that are undetectable by most geochemical analysis equipment making this method ineffective (Breiter et al. 2013);(Bruggencate et al. 2013).

Secondary Ion Mass Spectrometry (SIMS) explained by Bruggencate et al. (2013 page 2705) as "Combines the sensitivity and multi-element isotopic capabilities of mass

> spectrometry with minimally micro beam sample ablation and ionization."

Through ablation and ionization of the silica tetrahedral trace elements, quantities of impurities may be identified through comparison from quarry site samples. This method has proven to be effective in sourcing quartz crystal tools due to its accuracy down to parts per billion (ppb). Accuracy in ppb is necessary when working with pure quartz crystal material due to the low level of isotopic impurities (Bruggencate et al. 2013). Although SIMS is a destructive process, the amount of material destroyed is small, making it a viable option when sourcing quartz crystal lithic tools. SIMS sourcing has not received much use at the time of this writing (Bruggencate et al. 2013).

Quartz crystal sourcing has made great strides in the recent past using geochemical analysis. The various methods explained above are tools that can be employed to help establish provenance of source materials but it must be reiterated that these methods are not effective in isolation and must be combined to create a multi-approach methodological analysis using both geochemical and visual characteristic analysis (Bruggencate et al. 2013). Given the consistent use of quartz in the archaeological record perhaps future development could result in a standardized method that could reliably source material provenance.

CHAPTER 3: GEOLOGY OF THE CLEARWATER RIVER BASIN

Overview of the Clearwater River Basin Geology

Idaho is known for its wondrous diverse geology and many geological formations, from the newest lava formations of the Craters of the Moon National Monument in the south-central part of the state, to the massive silver loads pulled from the Coeur d'Alene River Basin. The Clearwater River can be divided into three basic geological areas; north, south and west. The north area is dominated by a large geological formation known as the Belt Supergroup (isu.edu 2014). The southern half of the Clearwater Basin is part of the Idaho Batholith. While to the west the Columbia Plateau extends into Washington State. The next three sections are detailed descriptions of these areas and their sub-formations and geologic qualities. Figure 10 is a map of the regional geological formations of the state of Idaho.

The North Fork of the Clearwater River

The North Fork of the Clearwater River and its tributaries are part of the Belt Supergroup and geologically distinct from the rest of the Clearwater River. The Belt Supergroup consists of diverse mineral deposits and geological characteristics that are part of old metamorphic formations from the Paleoproterozoic to the Mesoproterozoic era, approximately 2400 -1600 mya. The general mineral formations are composed of metamorphic sandstone, shale, and limestone (isu.edu 2014).

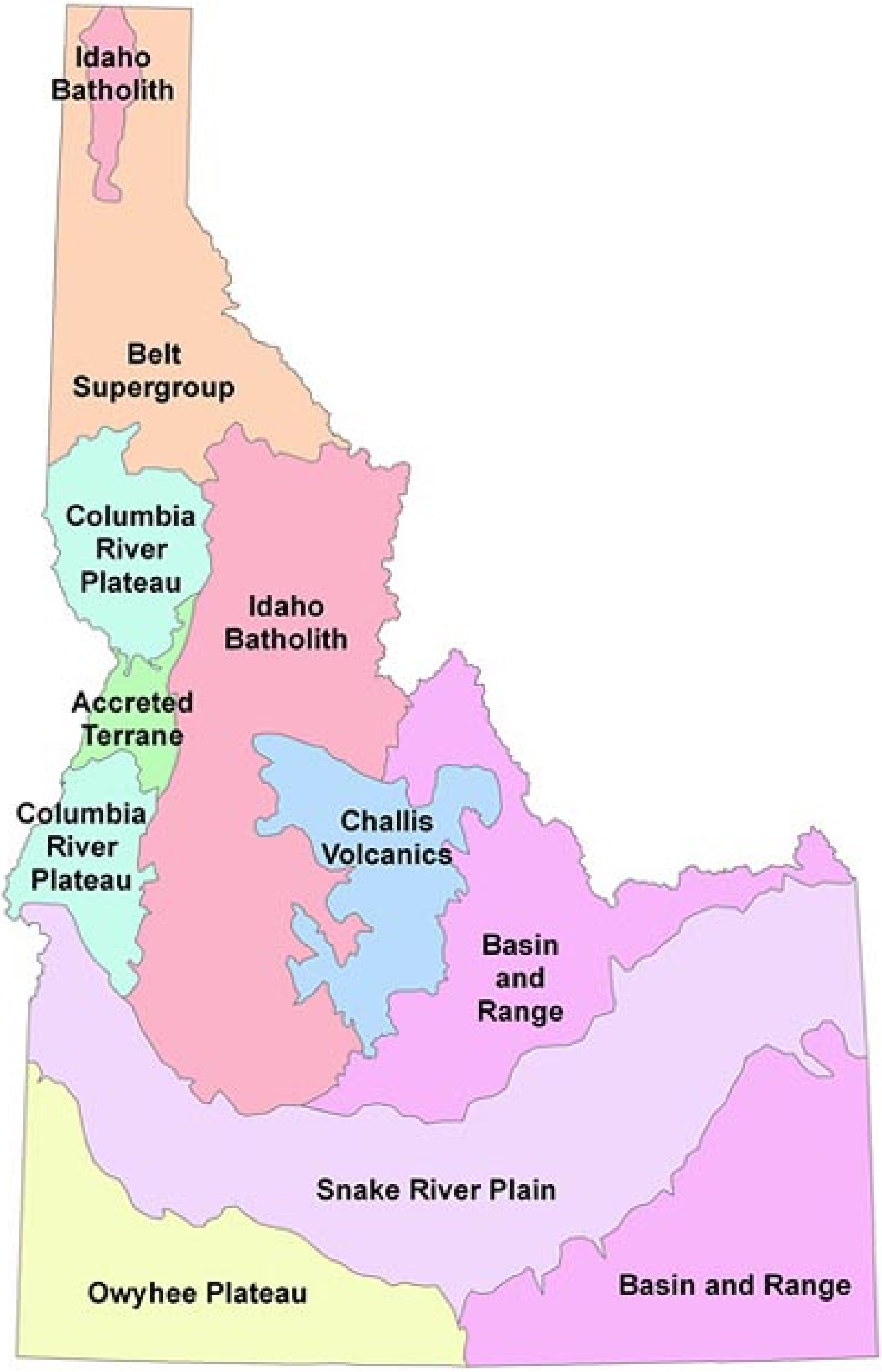

Figure 10. Geologic map of the state of Idaho showing major geologic features. Retrieved from: http://geology.isu.edu/Digital_Geology_Idaho/Intro/GeologicProvinces.jpg 2015.

The Windermere Group is a sub-feature formation of the Belt Supergroup. It dominates the southern portion of the Belt Supergroup and is composed of mature quartzite, biotite schist, and minor calc-silicate. Other mineral formations that are included in the Northern Belt Thrust include metamorphic rocks from the Paleoproterozoic and Archean eras about 2650 mya, composed of schist, gneiss, and subordinate quartzite along North Fork Clearwater River and Kelly Creek granite gneiss northeast of Pierce (idahogeology.org 2014). The Ravalli Group, another part of the Belt Supergroup, formed during the Mesoproterozoic and is composed of feldspathic quartzite, subordinate siltite and argillite, including garnet-grade quartzite and schist (idahogeology.org 2014).

Over millions of years these rock formations were compressed under heat and pressure to form metamorphic rock strata and deposits. Later erosion and uplift exposed the metamorphic bedrock forming what is commonly known today as the Bitterroot Mountain Range. This bedrock is rich in silicates, which under the right circumstances can be precipitated out to form quartz crystals (idahogeology.org 2014).

The South Fork and Middle Fork of the Clearwater River

At the town of Kooskia is the convergence of the South Fork of the Clearwater River and the Middle Fork of the Clearwater River. Upstream of Kooskia flows the Middle Fork of the Clearwater River with its large tributaries the Lochsa River, Selway River, and Moose Creek which are mostly found within the northern boundary of the Idaho Batholith. The South Fork of the Clearwater River is completely within the Idaho Batholith and exposed bedrock formations are consistent with Idaho Batholith characteristics.

The Idaho Batholith is a Late Cretaceous geologic formation consisting of intrusive igneous Granodiorite and Tonalite. These granitic formations were later uplifted and subject to erosion during the Paleocene creating the rugged river and mountain terrain so typical of central Idaho (isu.edu 2014).

Smaller formations of igneous rocks are also found in and along the northern edge of the Idaho Batholith. These formations include granodiorite with potassium feldspar megacrysts from about 70 mya. Later, about 47-43 mya, the Challis Volcanoes Formation, with its shallow roots, extended up into the southern boundary of the Belt Supergroup. These volcanic roots deposited quartz monzodiorite and subordinate diorite, granite, and subvolcanic dacite, along with granite, syenite, rhyolite, and the Lolo Hot Springs Plutons (idahogeology.org 2014).

The Columbia Plateau

To the west of the Belt Supergroup and Idaho Batholith is the Columbia Plateau. The point of convergence of these three geologic zones runs from the vicinity of the town of Pierce up to Orofino and the Dworshak Dam. From this point of convergence the Central Plateau extends into eastern Washington. It consists of volcanic basalt and rhyolitic flows from the middle Miocene about 16-17 mya, but some newer flows are present as late as the Holocene epoch (isu.edu 2014). Significant to this study is the deposition of microquartz crystal formations in vacuous spaces within the basalt and rhyolite flows of the Columbia Plateau. As is common with this type of matrix, small to medium gaseous bubbles form as the material cools, along with faults and fracturing creating voids within the flows. These spaces or vugs, under the right conditions can be filled with micro crystalline fibrous quartz from hydrothermal silica precipitate. As discussed earlier these multiple forms of silica-based deposits are more common than megaquartz crystal formations. The proximity of the lava and rhyolite flows of the Central Plateau and availability of this form of silica to the

Clearwater River Basin provided reliable close sources of silica material resulting that the majority of lithic tools in the area were manufactured from these types of cryptocrystalline quartz. This seems to be consistent through time.

The intersection of these three zones is represented in Figure 10. This color coordinated map shows the young pink formations of the Idaho Batholith to the south, the orange formation of the Central Plateau and the green formations of the Belt Supergroup to the north. For color feature descriptions see the key in Figure 11.

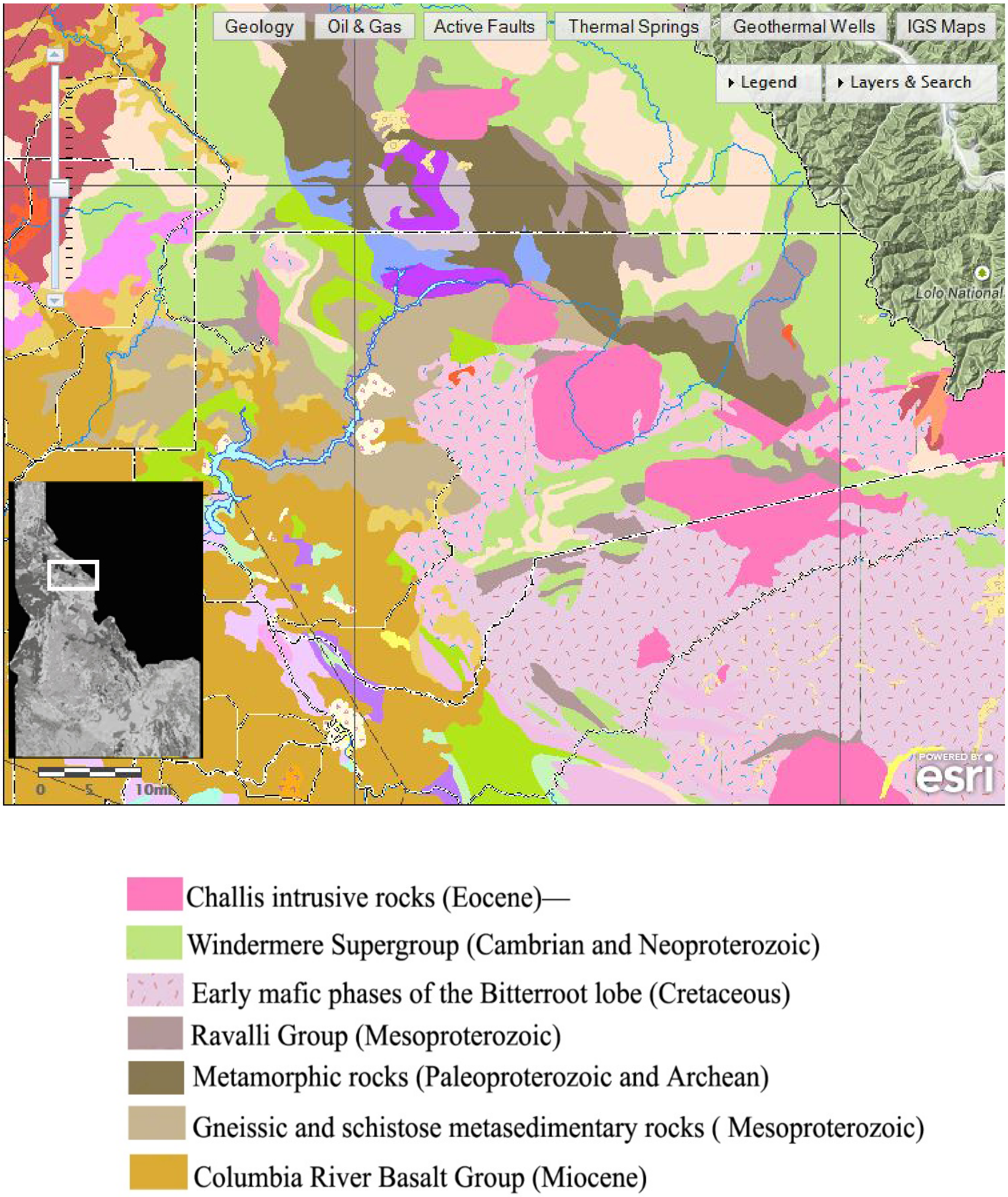

Figure 11. Geologic map showing the intersections of the Belt Supergroup, Idaho Batholith and Cental Plateau.
Taken and altered from: http://www.idahogeology.org/webmap/ 2015

Quartz in the Clearwater River Basin

It is significant that the convergence of these three geologic zones coincide with the highest density of quartz crystal lithic tools found within the Clearwater River Basin. As discussed earlier the formation of quartz crystal is dependent on an uplift of igneous material intruding into a silica rich bedrock. The Belt Supergroup being older than the Idaho Batholith and rich with sandstone, schist and limestone provided the perfect scenario for this occurrence. As the younger Batholith intruded into the Belt Supergroup molten magma plutons propagated the formation of pegmatites and the growth of megaquartz crystal. After millenia, erosion and glacial action has exposed some of these pegmatite formations making them accessible. Contrasted with the northern geological region of the Clearwater Basin, the southern region has fewer known areas of megaquartz sources. A dividing line between the northern region and southern region can roughly be drawn along the Lochsa Canyon. Reportedly there are known sources of megaquartz crystal found along the Middle Fork of the Clearwater River (Sappington 1988, 1996). Allowing for ecological mapping errors we may assume that megaquartz crystal pegmatites should also exist south of the canyon but at the time of this writing I am unaware of any major sources.

CHAPTER 4: QUARTZ TOOLS FROM SITES OF THE CLEARWATER RIVER BASIN

I reviewed the artifacts of the Clearwater River Basin collections and reports to establish the use and frequency of megaquartz crystal tools. This review included all major excavations that have been performed (Sappington 1996). Table 2, with associated map (Figure 12) shows site names and associated quartz artifacts.

Site Name	Site number	Mega quartz artifacts	Mega quartz crystals	Mega quartz debitage	Map Number
Hatwai					1
Spaulding					2
Arrow Beach			●		3
Lenore					4
Clearwater Fish Hatchery					5
Ahsahka’s Sportsmen’s access					6
Canoe Camp					7
Dworshak Dam		●		●	8
Weitas Creek			●	●	9
Six Mile Creek					10
East Kamiah					11
East Kamiah Waterline					12
Kooskia Bridge					13
Tuhkaytahs’peh					14
Kam’-nak-ka					15
Pete King Creek					16
Beaver Flat					17
Boulder Creek Complex					18
O’Hara Bar					19
Moose Creek					20
Bear Creek					21
Yahkanima’puh					22
Kelly Forks		●	●	●	23

Table 2. Archaeological Sites with quartz crystal frequencies and associated map numbers.

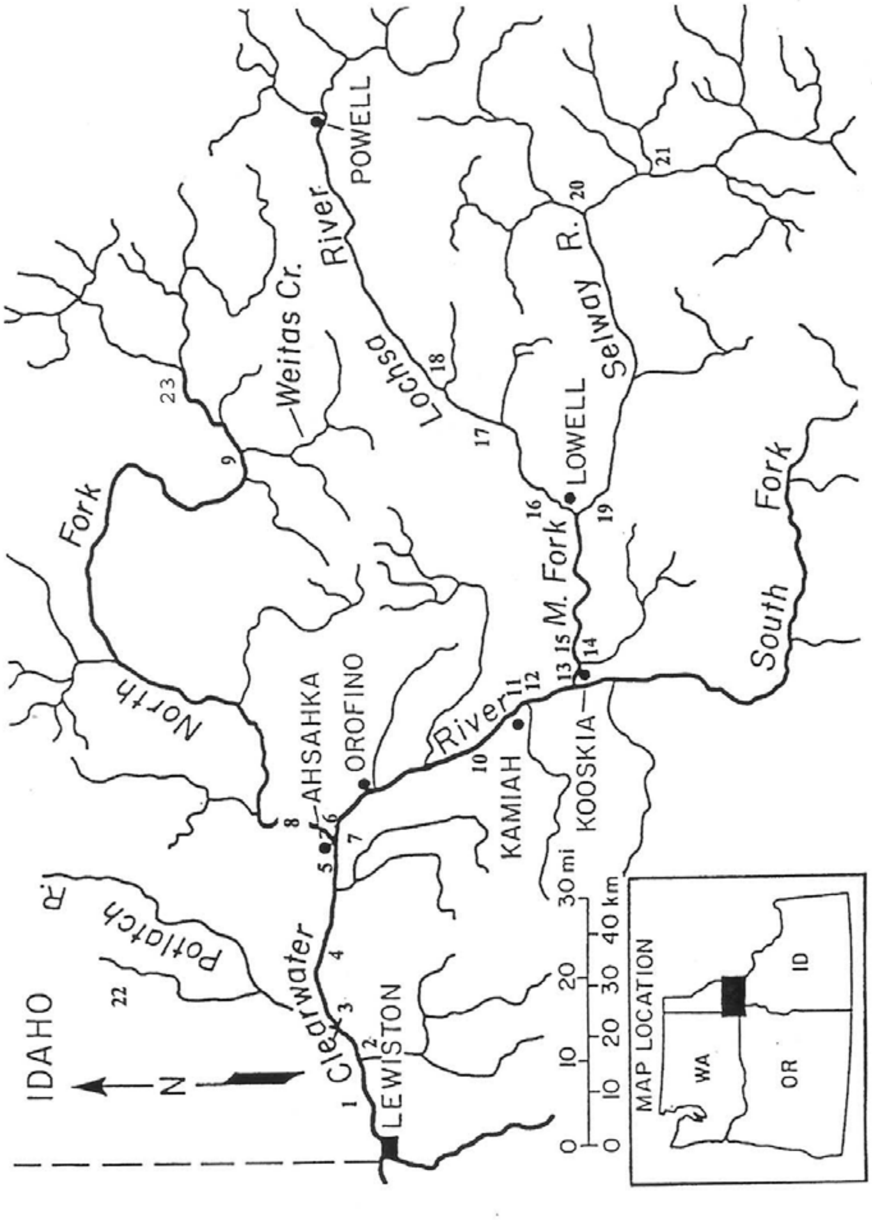

Figure 12. Location of key sites in the Clearwater River Basin. 1, Hatwai; 2, Spalding; 3, Arrow Beach; 4, Lenore; 5, Fish Hatchery; 6, Ahsahka Sportsmen's Access; 7, Canoe Camp; 8, Dworshak Dam; 9, Weitas Creek; 10, Six Mile Creek; 11, East Kamiah; 12, East Kamiah Waterline; 13, Kooskia Bridge; 14, Tuhkaytahs'peh; 15, Kam'-nak-ka; 16, Pete King Creek; 17, Beaver Flat; 18, Boulder Creek Complex; 19, O'Hara Bar; 20, Moose Creek; 21, Bear Creek; 22, Yahkanima'puh; 23, Kelly Forks Guard Station.

Adapted from: Sappington 1996.

Table 3 below, lists the sites where quartz crystal tools were recovered and their descriptions when available. The table also designates the occupation levels.

Site	Artifact Type	Quantity	Length Range cm	Width Range cm	Thickness Range cm	Weight grams	Occu-pation Level
Arrow Beach*	Quartz crystal	2	n/a	n/a	n/a	n/a	n/a
Dworshak Reservoir**	Quartz Debitage	5	0-70	0-44	1-20	1-72	Surface & 1-20
Weitas Creek***	Debitage	n/a	n/a	n/a	n/a	n/a	All levels
	Bifaces	32	4.85	2.85	.63	n/a	All levels
	End Scrapers	1	n/a	n/a	n/a	n/a	All levels
	Side Scrapers	6	4.89	2.95	0.95	n/a	All levels
	Gravers	4	1.5-3.0	0.7-1.3	n/a	n/a	Occu-pations I, II, III
	Quartz crystals	3	n/a	n/a	n/a	n/a	Occu-pations II &IV
Kelly Forks****	Debitage	552	n/a	n/a	n/a	n/a	All Levels
	Flake Tools	11	14.3-43.7	7.3- 32	2.8- 18.3	0.32-10.4	Level 11
	Preforms	1	32.1	29	9	9.46	n/a
	Point Fragment	1	25.5	17	5.5	2.06	n/a
	Biface Fragment	4	4.9- 29	5.6- 21.8	4- 16.5	0.33- 3.8	1 at level 15
	Other Flaked Items	4	20.3- 60.2	10.4- 39.5	7.9- 10.5	3.7- 15.8	n/a
	Non-core Tools	3	21.1- 188	14.4- 214	13.5- 79.1	3.8- 2640	n/a

Table 3. Descriptions of quartz crystal tools from Clearwater River region. *Taken from Toups 1969; ** Taken from Mattson 1983; ***Taken from Keeler 1973; **** Taken from Longstaff 2013.

Possible Prehistoric Quartz Crystal Quarries

As stated before, there is reportedly a known quartz crystal source located within the Lochsa River Canyon. Its exact location is unknown at the time of this writing. Other sources are sure to exist within the region due to the geologic makeup of the terrain, and it may be assumed that many currently unknown quartz crystal sources may have been known by ancient peoples or have been exploited to exhaustion.

In 2013 I met William Mabutt, a local gentleman from Moscow, Idaho. Bill, as he is called, owns Gem State Crystals, a gem and jewelry business in downtown Moscow and has over 30 years in the gem collecting and sales industry. We frequently discussed the topic of local geology and rock collecting in the area. I had more than just a passing interest because I wanted to know of local sources of lithic material that may have been collected anciently. Our conversation turned to the Clearwater River and quartz crystals. Bill apprized me of a large quartz crystal deposit near the area of the North Fork. He later showed me photos from the 1970s of the location and some of the large crystals from the source.

The collection site is located in the Bitterroot Mountains at the headwaters of the Middle Fork of Kelly Creek. The exact location of the source will not be given in this report to protect the source from unscrupulous collectors. The elevation is above 6,000 feet and near the Bitterroot divide on the Montana-Idaho border. Access to the collecting site is very remote requiring a great deal of rugged backcountry travel both in four-wheel drive vehicles and by foot. Navigation to the collection site is complicated and requires knowledge of the local terrain and backcountry travel. I highly discouraged anyone from attempting to locate and collect from the site.

The collection site is located high on the northern slope of the mountains. A large bedrock outcropping dominates the steep hillside and is approximately 300m by 600m of exposed granite (Fig. 13) At some point in the 1900s the site was a location of a fluorite mine that was being extracted for industrial use (Mabbutt Personal Communication 2014). Large quartz crystals were also present at the mine but were ignored by miners and much broken and discarded quartz material is spread through the tailing piles downhill from the mine itself. During the mining operation a massive pegmatite was opened up in the granite and is reportedly “large enough to hold a train car” (Mabutt Personal Communication 2014). Found throughout the pegmatite were large crystals of fluorite, quartz and other minerals, and the large pegmatite was stripped clean. Years after mining operations ceased other smaller pegmatites were discovered in the same area. Up until recently the pegmatites were not mined for their mineral contents. One of the pegmatites was said to have a single quartz crystal 14 inches in diameter and over 3 feet in length. This massive single quartz crystal would have weighed over 400 lbs. and been extremely difficult to extract from the pegmatite and transport miles back to the nearest road. Sadly in the recent past it was removed by an unknown party and its whereabouts are unknown (Mabutt Personal Communication 2014).

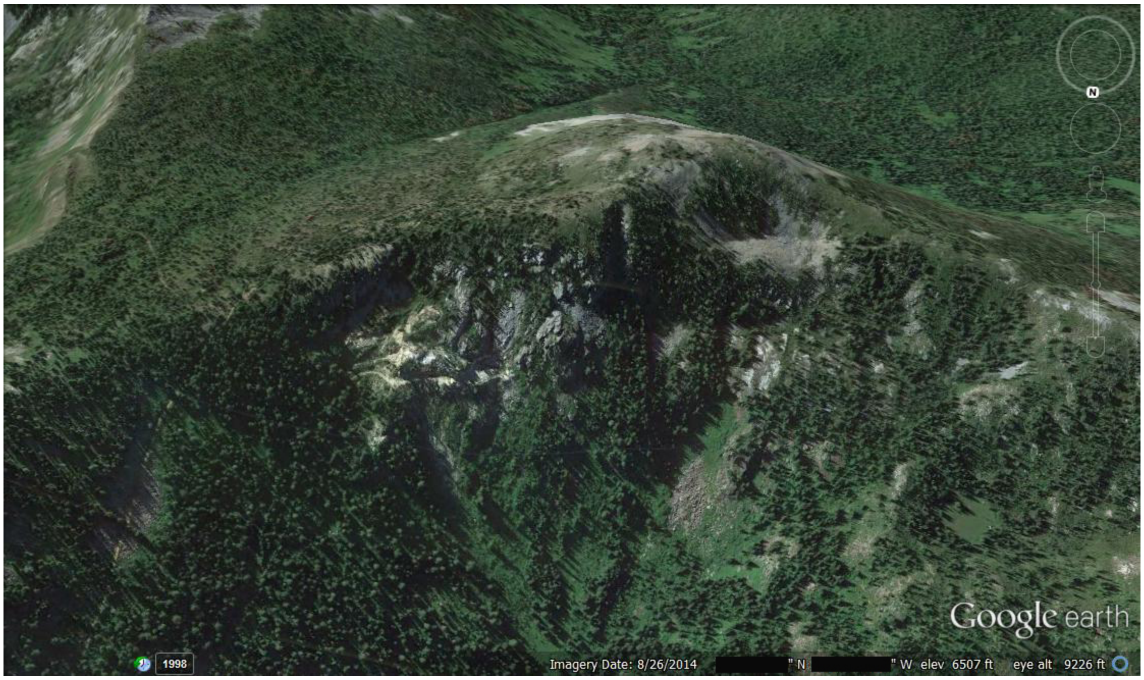

Figure 13. Satellite image of the topography of the fluorite mine site. No cardinal directions or geographic coordinates were given to protect its location.
Image taken from: Google Earth 2015

Soon a discussion on the topic ensued that would last over a period of over a year. I was aware that quartz crystal tools had been recovered at both Kelly Forks and Weitas Creek archaeological sites. Sourcing of the quartz artifacts at Kelly Forks and Weitas Creek has not been done due to the lack of accurate sourcing methods and knowledge of local sources in the North Fork of the Clearwater River. The news of a known source of large quartz crystals in the area was encouraging.

In the fall of the same year Bill approached me and said he had taken a trip up to the area to do some rock hounding, and had brought back some specimens for examination he wanted to give me. This led me to the choice to take on this topic for my Master's thesis. He

Figure 14. Mr. William Mabbutt holding a large single quartz crystal recovered near the North Fork of the Clearwater River.

had also recovered some nice specimens, which I photographed (Figures 14, 15 and 16). Figure 15 is a unique crystal that has many small pyrite inclusions in the crystal growth. Figure 9 shows these same inclusions close up. These types of inclusions are rare and could be useful to source the material by visual characteristics.

Figure 15. Large quartz crystal recovered from near the North Fork of the Clearwater River. Scale is in cm.

Figure 16. A second large quartz crystal recovered from near the North Fork of the Clearwater River. Scale is in cm.

The material used in the manufacture and use-wear analysis portions of this work was provided by Mr. Mabutt from this source. The source lies within reasonable distance of the archaeological sites of Kelly Forks and Weitas Creek and could be the origin of the lithic tools recovered from both sites. Further research is necessary to establish conclusive evidence if this is true.

The rugged terrain of the North Fork of the Clearwater makes discovering new potential sources difficult but it is certain that there are other areas that contain quartz whether vein quartz or crystals. It is a matter of finding and documenting the possible sources.

In December 1995 heavy rains and snow loads in the North Fork area resulted in a giant landslide on Quartz Creek, a tributary of the North Fork of the Clearwater River downstream from the archaeological site of Weitas Creek. The slide was reportedly 60 feet across and 600 feet long and approximated 500,000 tons of rock, mud and dirt. It was the largest slide in the state of Idaho during the unusually high precipitation year of 1995 (Pacific River Council 1998). The debris field covered the entire canyon bottom, damming the creek and destroying the road. The overburden failed completely to bedrock and exposed large quantities of granitic and quartz rocks. The bedrock of the area is illustrative of the many potential locations of quartz crystal that may have been available to ancient inhabitants of the area (Spokesman.com 1995). If further research was taken to explore debris of this slide, the possibility exists to document the presence of quartz crystals.

Figure 17a shows satellite imagery from 1998, three years after the slide occurred. Figure 17b was taken in 2013 and illustrates the dramatic change in vegetation growth on the debris surface between 1998- 2013. The rapid regrowth of vegetation makes it possible to assume that many areas that may have been exposed anciently and exploited for lithic material are not exposed today. Archaeologists that wish to look for potential source sites must assume that not all sources will still be identifiable in such rapidly changing terrain.

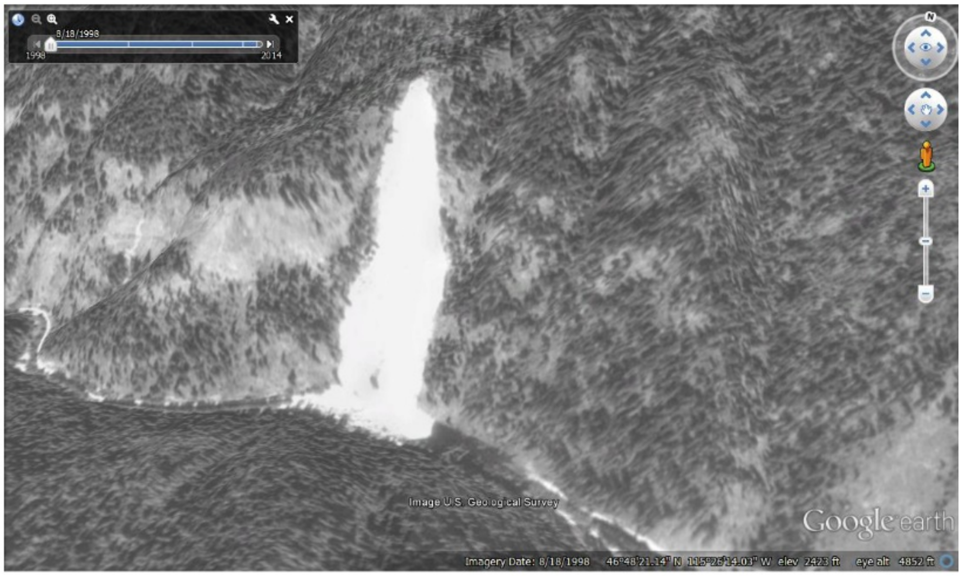

Figure 17a. Top image of the Quartz Creek landslide recorded in 1998. Figure 17b. Lower image shows the dramatic vegetation growth between 1998 and 2013 when the second image was recorded.
Used From: Google Earth 2015.

Satellite and aerial photos of the area also show with certainty the many mountain granitic uplifts of the towering Bitterroot Mountains within the vicinity that are geologically capable of producing pegmatites containing quartz crystals. One such outcropping lies directly above the river on the north side near Weitas Creek. Figures 18a, b and c are Google Earth views of this outcropping. Figure 17a was taken from the river. The outcropping is granitic in nature and most likely is composed of a high percentage of quartz and possibly contains pegmatites with quartz crystals. If so, ancient peoples could have exploited this source.

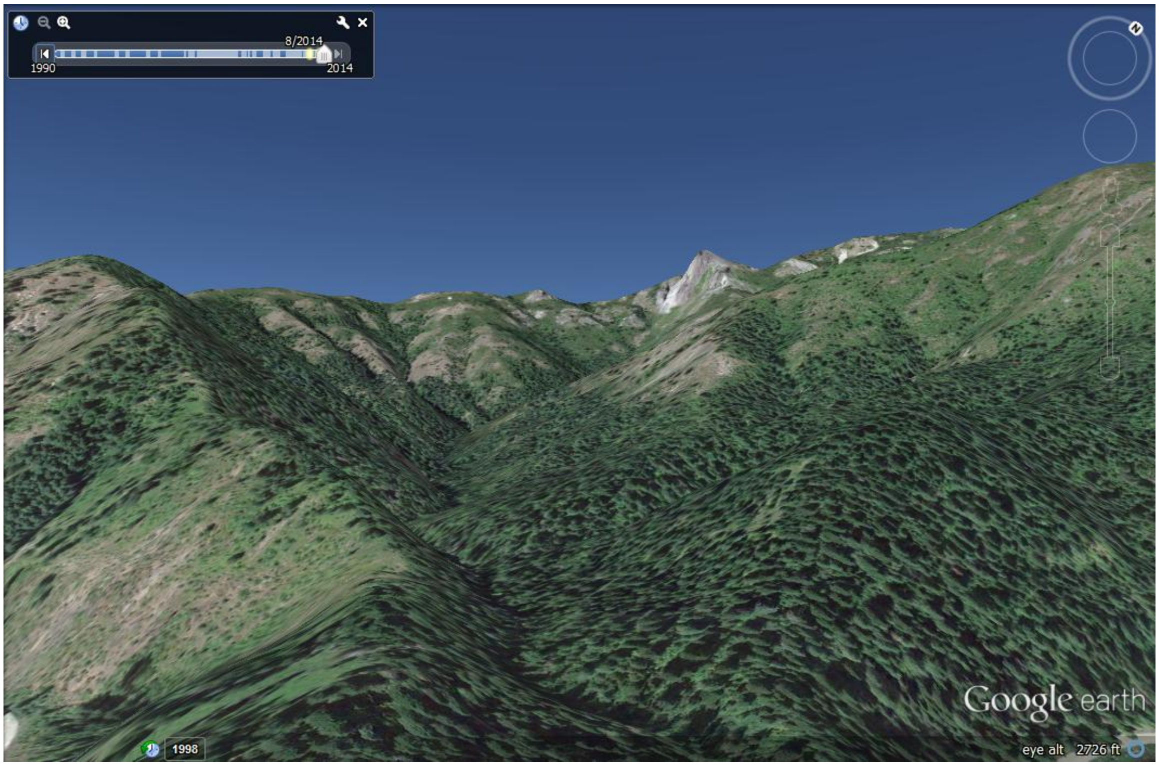

Figure 18a. Granite outcropping seen from the North Fork of the Clearwater River. This lies close to site at Weitas Creek and could have been the source of quartz crystal raw material. Used From Google Earth 2015.

Figure 18b is a close up of the same granite outcrop. The scale of its image is deceptive but the overall height of the exposed rock is over 700 feet high and runs more than 1,100 feet of the ridge length. If compared with the quartz source from Figure 12, the granite outcrop above Weitas Creek is nearly 60% the same size in this one single monolith, but it is not an isolated exposure of bedrock in the area but rather the largest of many exposed rocks as shown in Figure 18c.

As a potential quarry site for quartz crystal lithic material this site must be investigated, and further examination of this area could provide more information into quartz crystal availability near the Weitas Creek archaeology site.

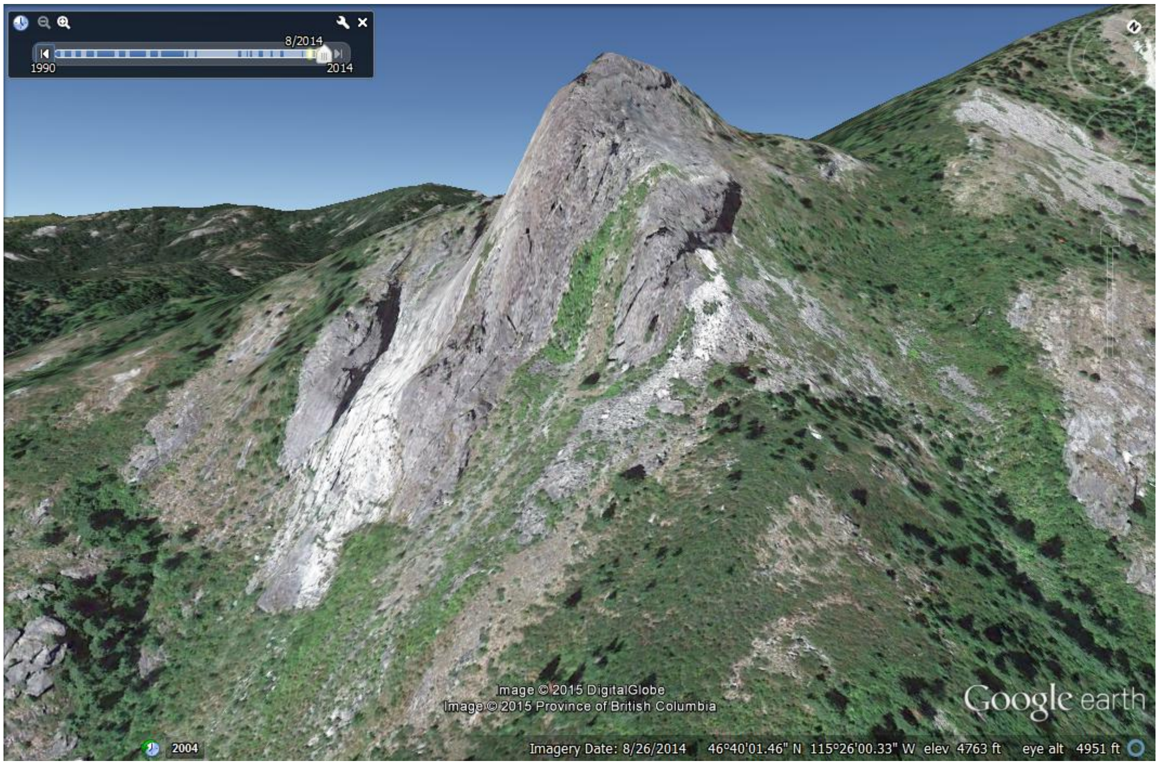

Figure 18b. A close up image of the monolith above the Weitas Creek site. The height of the exposed rock is over 700 feet high and is a potential site for quartz crystal pegmatites. Used From Google Earth 2015.

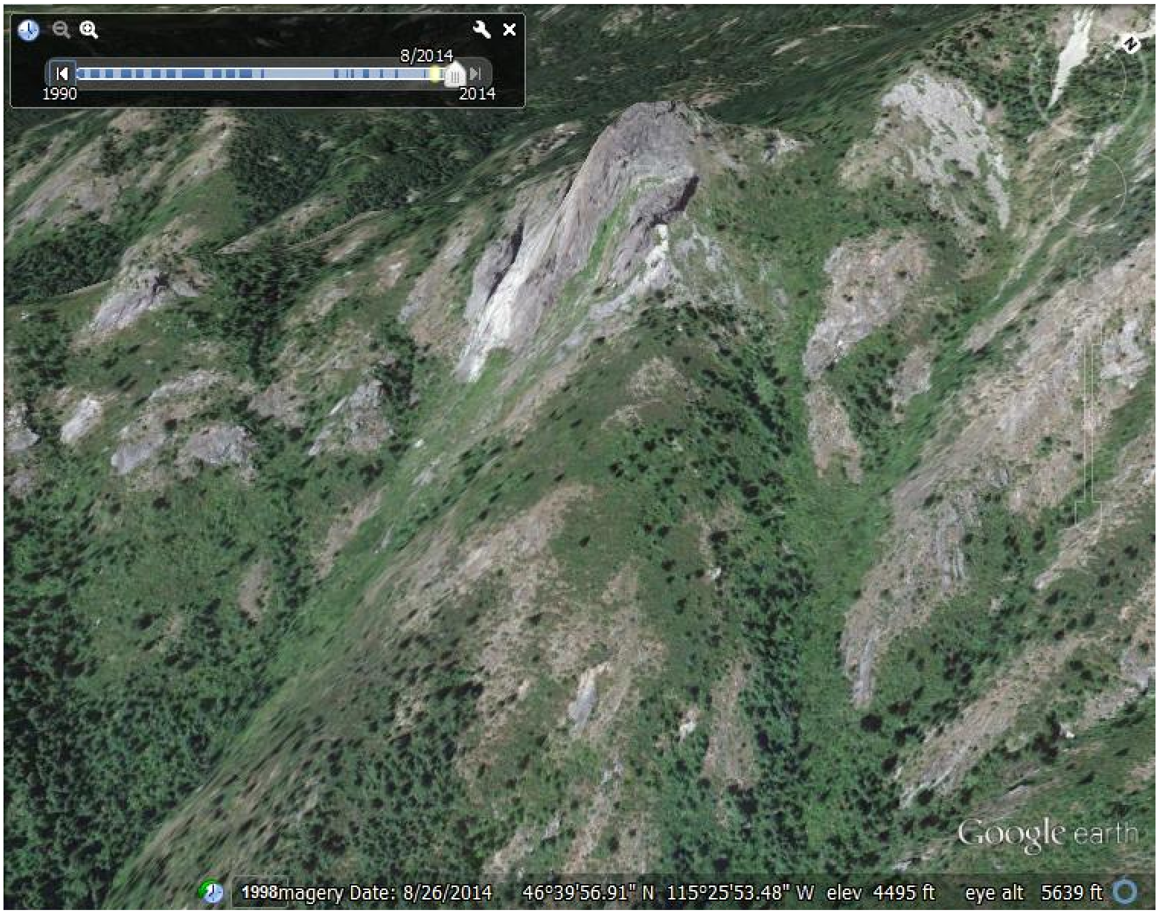

Figure 18c. Satellite image of the entire granite outcrop on the ridge above Weitas Creek. Note the center monolith which has a height of over 700 feet. The granite bedrock may contain pegmatite quartz that could have been exploited by ancient peoples.
Used From Google Earth 2015.

CHAPTER 5: EXPERIMENTAL TECHNIQUES IN QUARTZ TOOL MANUFACTURE

Theory

By far, the largest percentage of ancient humankind evidence found in the archaeological record is represented by stone tools (Crabtree 1975). It is not my intent to review the history of lithic tool making or the more recent renaissance of the study of lithic tool manufacture. Many volumes have been written compiling the current knowledge of lithic tools, and readers can approach this subject easily.

Flenniken defined lithic technology as “the study of the development by man [humans] of the techniques for the modification and functional use of stone” (Flenniken 1981). For my purposes this definition will suffice.

Replication of ancient stone tools has been an interest of modern peoples for more than a hundred years and became formally a study in archaeology in the last century (Johnson 1978). Replicative manufacture of lithic tools has given great insight into the complex and diverse behaviors associated with stone tool production and use, but the complete life of a tool from selection of raw material to deposition into the archeological record requires a more complex and complete model. Flenniken, in 1981, suggested as a theoretical model the use of Replicative Systems Theory. Replicative Systems Theory is related to General Systems theory which was developed by Ludwig von Bertalanffy in 1937 (Bertalaffany 1950), and can be considered a specific application of its principles, but it differs in that Replicative Systems Theory is focused on a particular behavior that contains units of commonality. In this study, the replication of quartz crystal tool technology of the past and all behaviors directly affecting quartz tool manufacture and use is the behavior considered.

It is my opinion that replicative systems analysis of quartz tools can only be applied to the systemic context from which those tools arose and archaeological processes that alter artifacts cannot be accounted. Also results can only be viewed accurately as far as the end observations are not contrary to archaeological data.

If Replicative Systems Analysis theory is used to describe quartz crystal tool lithic manufacture and use-wear, the complete life of a quartz lithic tool should be replicated. According to Flenniken this analysis would include the many steps that the tool may have gone through including selection of raw material, heat treatment, reduction, hafting, use and functions, and final discard or loss into the archaeological record.

For this study the Replicative Systems Analysis theory in its totality will not be used but rather only parts of Flenniken's suggested model. The reason for derivation from the complete model lies in the lack of archaeological evidence that supports parts of the known systemic quartz tool manufacture and use for the Clearwater River data.

The model proposed by Flenniken for the Hoko River site in western Washington contains six subsystems within the replicative system theory: (1) selection of raw material; (2) heat treatment; (3) reduction into tools; (4) hafting of tools; (5) use or function of tools, and (6) rejuvenation of tool edges and discard of tools. Using Flenniken's model this study will omit subsystem 2, 4 and 6.

Subsystem 2 is the replication of heat treatment of the raw lithic material used at Hoko River. The lithic material at Hoko River was vein quartz that had been tumbled by river and glacial action. Evidence of heat treatment was found at Hoko River and so it was appropriate that it be a subsystem of Flenniken's analysis. Conversely neither of the sites of Weitas Creek or Kelly Forks give evidence of the use of heat treatment, thus subsystem 2 has been eliminated from this replicative systems analysis. Subsystem 4 of the model is a hafting of the tool to a handle. This subsystem has also been eliminated due to the lack of evidence that it was a common practice. Subsystem 6 is tool edge rejuvenation after use. My interest concerned with the use of quartz crystal tools is in edge deformation and dulling. I found edge rejuvenation an unnecessary step in recording my intended results.

The Replicative System Analysis model I propose contains the remaining three subsystems to describe the manufacture and use of quartz tools. Three of these subsystems will be performed to produce and perform a use-wear analysis on the tools; raw lithic material selection, reduction of material into tool forms, and use of tool forms. This theoretical model's purpose is to organize empirical data that is recovered through the manufacture of quartz crystal lithic tools. My hope is that through this model we might see the replication of the decisions and techniques of the past performed by a modern flint-knapper. It is perfectly understood that knowledge and techniques of the past may vary somewhat from this experiment, but overall we should be able to grasp how an ancient human may have interacted in daily routine with this material. The results from the experiment should be able to be interpolated to understand how quartz crystal was used in the Clearwater River Basin.

The following chart (Table 4) shows the theoretical model I have chosen to follow. This model is a simplified version of reality and is not able to completely account for behaviors and variables unknown to me in the present. The model is split into two contexts:

the systemic context reflects a quartz tool’s life from selection, manufacture, use, curation, and then discard or loss. After the tool is discarded it enters the archaeological context where it is buried in the archaeological record. It is notable that artifacts can be moved from the systemic context to the archaeological context and back again into the systemic context either for curation, reuse or rejuvenation. In other words the boundary between the two contexts is not a network of unidirectional flow, but a permeable border that allows tools to travel back and forth to be reused they had been discarded. This flow between contexts is common knowledge to modern archaeologists and is known to be an unpredictable variable which allows artifacts to cross barriers of time and culture without leaving evidence of context (Sappington Personal Communication 2014).

It should be said that the above-described theoretical model was used and altered from Flenniken’s Hoko River theoretical model that was developed from Bertalaffany’s theoretical model of general systems theory and I acknowledge these predecessors for their work (Flenniken 1981).

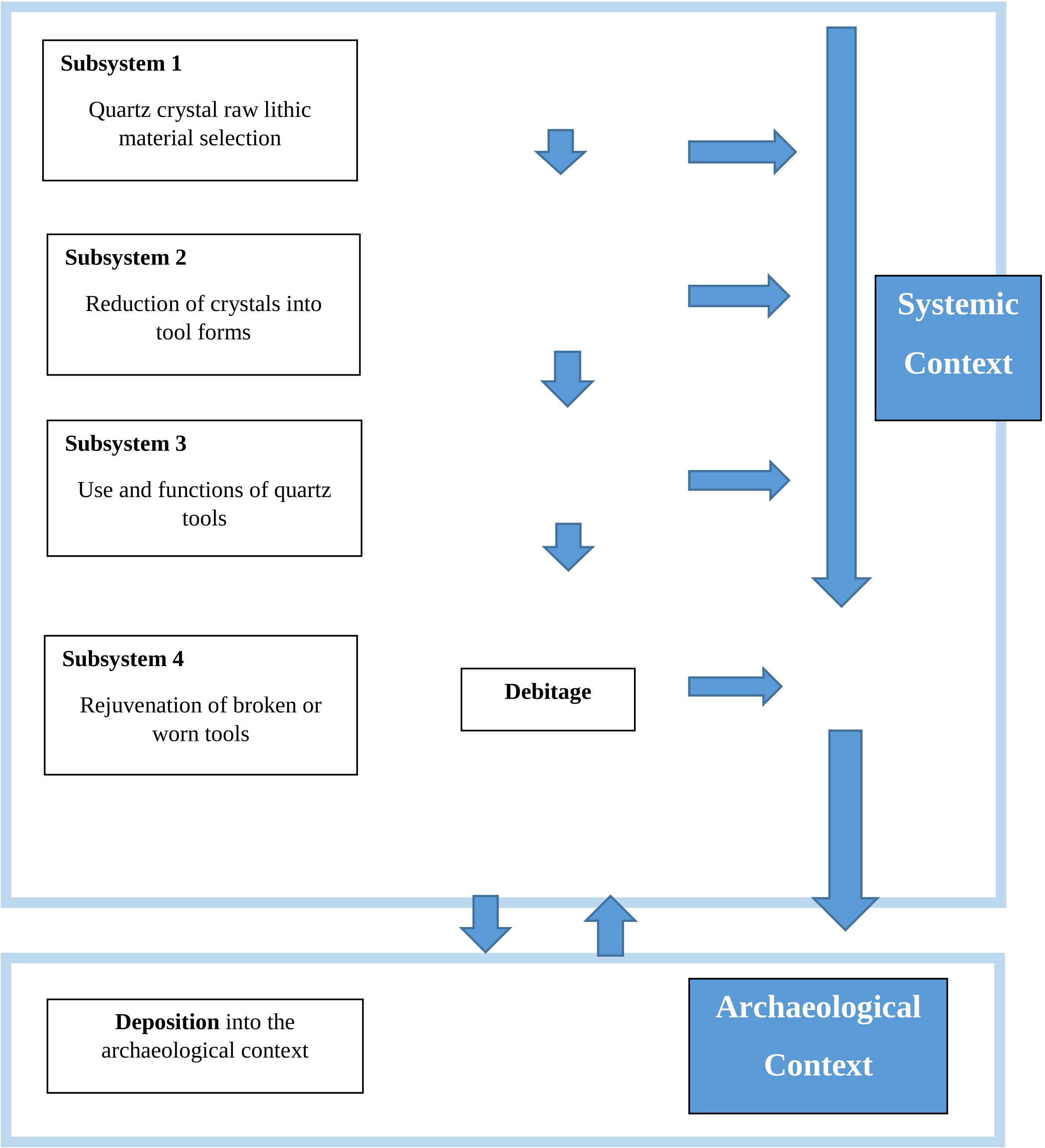

Table 4. Theoretical model showing the life of a quartz crystal lithic tool from raw material selection to deposition in the archaeological context.
Developed from Flenniken 1981.

Methods in Quartz Crystal Tool Manufacture

The following is a description of the steps and methods used in the replicative tool analysis of twenty single-sided megaquartz tools and five bifacial projectile points. The purpose of this replication section is to describe in detail the steps and results of the experimentation, thus allowing future researchers to replicate the experiment and look for similarities, variation and alternate results. This experiment is not intended to be definitive but rather to augment the vast body of knowledge surrounding the manufacture of lithic tools.

Quartz crystal tool manufacture is mentioned briefly by Crabtree in the article *The Flintknapper's Raw Materials* (Crabtree 1967: 10). I have included this brief excerpt of his evaluation in the following quote:

> *"Quartz crystal: The use of this variety for making tools was rare. Sources containing crystals large enough to make tools of adequate size are uncommon. When quartz crystal is used in the manufacture of flaked tools, it must be treated differently from cryptocrystalline varieties. …The quality depends on the degree of homogeneity … Many quartz crystals, however, do have … many cleavage planes of the growth pattern. The resulting artifact will be thick and ill-formed and no amount of skill can overcome the difficulties".*

As I prepared to begin the manufacturing portion of this research this quote was present in my mind. I was at the time of this writing a novice flint-knapper and have made a few dozen presentable tools of various use including bifaces, preforms, knives, and crescents, but to assume that I might be able to manufacture tools of a high quality from quartz crystal seemed highly unlikely.

As stated before, the material that I obtained for the manufacture and use-wear experiments were collected from the source at the headwaters of the North Fork of the Clearwater River and were given to me by Bill Mabutt. After inspection of the material I was convinced that it was similar in quality to quartz that is found in the collections from Weitas Creek and Kelly Forks. I also expected that manufacturing the quartz tools would be extremely difficult after reading Crabtree's description. I employed the help of Dave Quinn, a local experienced flint-knapper, to help guide me through the tool manufacture process.

Raw Lithic Material Used for Tool Manufacture

Reduction began with two fairly large sized pieces of quartz, from which I flaked 20 blades, 10 from each crystal. Of these 20 blades none of the edges were reworked or refined. Three other pieces of smaller crystal were also reduced to produce 5 biface projectile points. Every piece selected had some crystal faceting on the stone to indicate it came from a larger crystal. Table 5 describes each of the rocks chosen for reduction.

Crystals	Length	Width	Thickness	Weight	Visual Characteristics
Stone 1	12.1 cm	9.2 cm	6.6 cm	0.74 kg	Mixed clarity, many water inclusions near the ventral side. Cortex on dorsal side is fully formed crystal facets.
Stone 2	9.4 cm	6.1 cm	5.8 cm	0.28 kg	High clarity and uniformity throughout the entire stone. Little or no inclusions. Faceting on dorsal side of stone. Natural platform shape.
Stone 3	10.9 cm	6.8 cm	1.5 cm	0.10 kg	Foggy with water inclusions. Entire dorsal side is a crystal facet.
Stone 4	7.0 cm	5.0 cm	2.4 cm	0.12 kg	Very poor clarity with many water inclusions, visible fractures throughout. Small terminated crystal jutting from the faceted dorsal side.
Stone 5	6.8 cm	4.8 cm	2.0 cm	0.08 kg	Foggy clarity, but uniform. Many small pyrite crystal inclusions throughout. Faceting on the dorsal side.

Table 5. Descriptions of raw material selected for reduction.

Ideally the crystals selected would have been fully faceted, large, and clear. Unfortunately none were available from the collection site that fit this criteria that were not worth hundreds of dollars. The use of such valuable and rare crystals of this quality in experimental lithic tool manufacture was cost prohibitive for this study. The best quality of the available material was selected for reduction.

Quartz crystal’s clear silica material is prone to cracking, and if the cracks are fine and do not crush the material, the cracks are invisible. If water is present it will infiltrate the cracks and either create thin rainbow effects or a visible foggy appearance. All the stones selected except Stone 2 were infiltrated by water and as reduction commenced the water could be seen releasing out of the clear stone in little rivers running to the surface. At one point when Stone 1 was being reduced, there was an audible suction sound as the water could be seen following the fractures through the material. When this phenomenon occurred more often than not the material had oblique fractures present before reduction began and caused failure of the tool form.

This observation becomes important when selecting raw material; if the material has rainbows or is foggy, it would indicate water within the material and the presence of fine cracks. Only the clearest and most homogenous material is optimal for consistent and predictive reduction into preconceived tool forms. Material with rainbows and fog consistently cracked and resulted in failure.

Descriptions and photos of the tools used in the manufacturing process.

Three tools were used in the reduction of Stones 1 and 2, and pressure flakers for edge refinement on bifacially worked blades. To stay true to available ancient tools a moose antler billet and two river hammerstones of different sizes and weight were selected for primary reduction. Bone and antler pressure flakers were chosen for edge refinement. Figures 19a, b and c show photos of each of the primary reduction tools. Figures 20a and b show photos of the secondary stage reduction tools. Table 6 is the physical description of each of the five tools used.

Figure 19a. A moose antler billet was used for the primary reduction sequence. Scale in cm.

Figure 19b. Hammerstone #1, used in the primary reduction sequence. Scale in cm.

Figure 19c. Hammerstone #2 used in the primary reduction sequence. Scale in cm.

Figure 20a. Antler pressure flaker use in crystal tool edge refinement. Scale in cm.

Figure 20b. Bone pressure flaker in wood handle use in crystal tool edge refinement.

Reduction tools	Length	Width	Weight	Description
Moose Billet	18.2 cm	5.3 cm	320 g	Moose antler base, rounded at proximal end.
Hammerstone 1	8.2 cm	6.3 cm	400 g	Semi-round river cobble of metamorphic composition.
Hammerstone 2	9.8 cm	7.2 cm	320 g	Oval river cobble of igneous granite composition.
Antler flaker	15.5 cm	2.3 cm	26.3 g	Deer antler tip.
Bone flaker	19.5 cm	3.0 cm	43.3 g	Bone shaft inserted in wood handle.

Table 6. Descriptions of tools used to reduce stone in the experiment.

Description of Reduction and Resulting Flakes.

Reduction on Stone #1 (Figure 21a and b) was difficult and unpredictable. The material looked very clear on the dorsal surface and progressed to a completely foggy opacity on the ventral side. It became quickly apparent that the entire crystal, although it looked very clear, contained oblique cracks and moisture within. These oblique fractures limited the length of flakes that could be driven from the core. Eventually the core failed and broke into large chunks that were not optimal for creating more flakes. Many small thin flakes were produced, 10 of which were selected for the useware analysis portion of this study. I selected the flakes because they had at least one sharp edge and were the largest flakes produced. Final reduction and debitage are shown in Figure 22.

Figure 21a. Stone #1, fractured side. Scale in cm.

Figure 21b. Stone #1, cortex side showing crystal facets and clear material. Scale in cm.

Figure 22. Reduction results of Stone #1. Scale in cm.

Stone #2 (Figure 23a and b) reduction was more successful than Stone #1. Unlike Stone #1, Stone #2 was consistently clear through the entirety of the stone with no fogging or rainbow coloring. The shape of the stone also created a natural platform that was ideal for driving off long thin flakes. Many usable flakes were driven off the core before a large over-shot flake removed the lower portion of the stone. The decision was made to leave the remaining core to illustrate that with the correct quartz crystal stone it is possible to predict flake removal. Ten flakes were removed for the use-wear analysis portion of the study. Figure 24 shows the result of the reduction sequence.

Figure 23a. Stone #2 fractured side. Scale in cm.

Figure 23b. Stone #2, showing faceted side. Scale in cm.

Figure 24. Reduction results for Stone #2. Scale in cm.

Stones 3-5 were selected from the remaining raw material for reduction into bifacial projectile points (Fig. 25a, b and c). The points will not be included in the use-wear analysis but were made only to experiment with the difficulties of manufacturing with quartz crystal to fabricate projectile points. All three of the stones had crystal facets on the cortex indicating that they were originally portions of larger crystals. All three had heavy inclusions and as the reduction progressed oblique growth lines caused unpredictable fracturing.

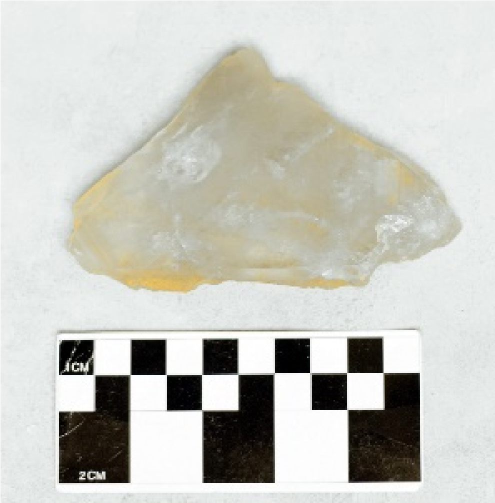

Figure 25a. Stone 3. Scale in cm.

Figure 25b. Stone 4. Scale in cm.

Figure 25c. Stone #5. Scale in cm.

This section of the analysis will focus on the reduction of Stone #2, because it resulted in the most successful removal of thin unbroken flakes. Quartz, like other silica-based minerals, has conchoidal fracturing properties. Conchoidal fracture removes material from the core resulting in sharp-feathered flakes that are excellent for cutting purposes (Whittaker 1994). The flakes removed from Stone #2 were the largest of the entire experiment. This is not surprising considering that Stone #2 had the fewest inclusions and fogging. The material proved to be homogenous and with no oblique growth angles. Figures 26a and b shows a flake that was removed using direct percussion with hammerstone #1. These flakes could easily be refined into any number of cutting tools. Photos 4 and 5 of the sequence shows the next flake resulting in an overshot removing the distal end of the crystal. This final flake also fractured into two parts either from the force of the percussion or from weakness in the material.

Figure 26a. Flake removed with direct percussion from Stone #2. Scale in cm.

Figure 26b. Flake and flake scar from direct percussion on Stone #2. Scale in cm.

Figure 27. Stone #2 overshot flake from direct percussion. Scale in cm.

Analysis and Photos of Final Lithic Tools.

The following photos are of the flakes removed from stone 1 and 2 described above. Only the flakes chosen for use-wear analysis are included. The 10 flakes removed from Stone #1 are represented in Figure 28. Figure 29 is the resulting flakes removed from Stone #2.

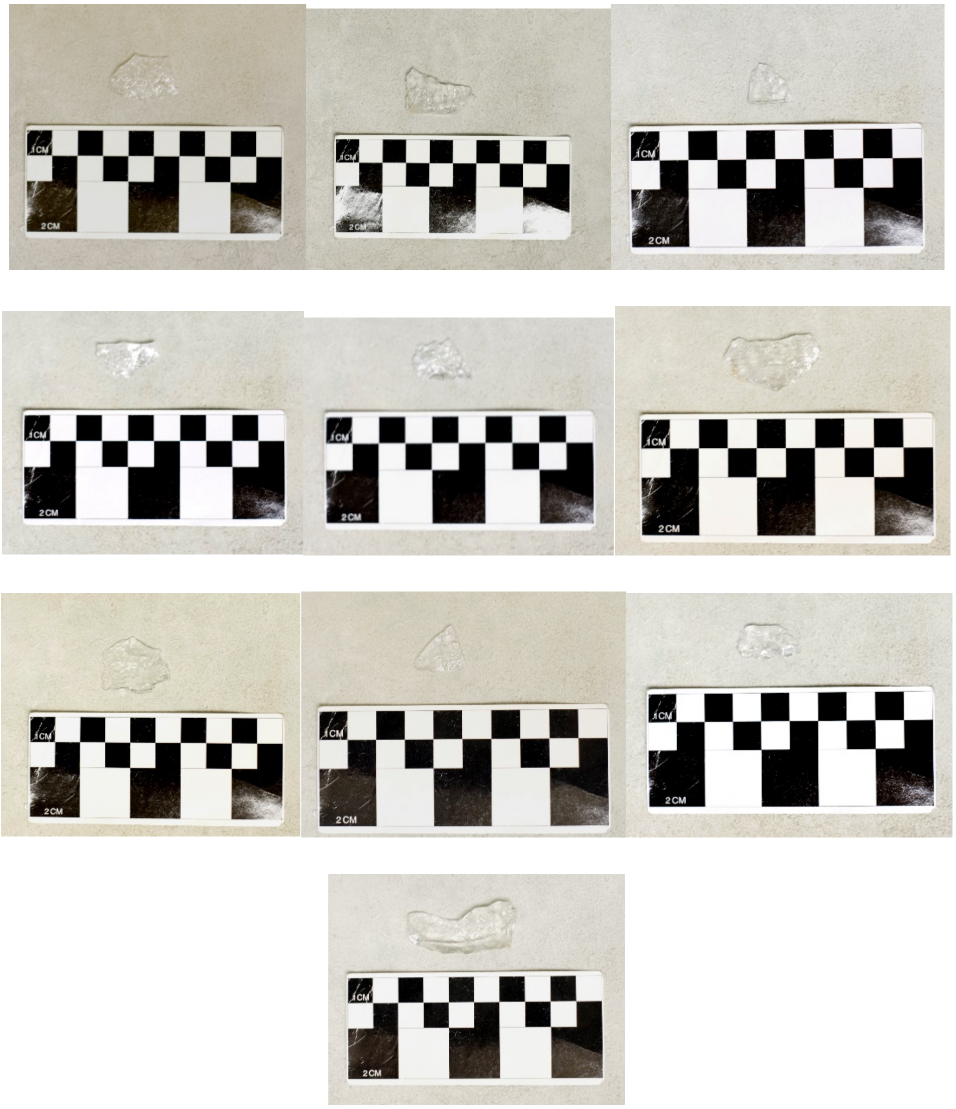

Figure 28. Flakes selected from Stone #1 for use-wear analysis. Scale in cm.

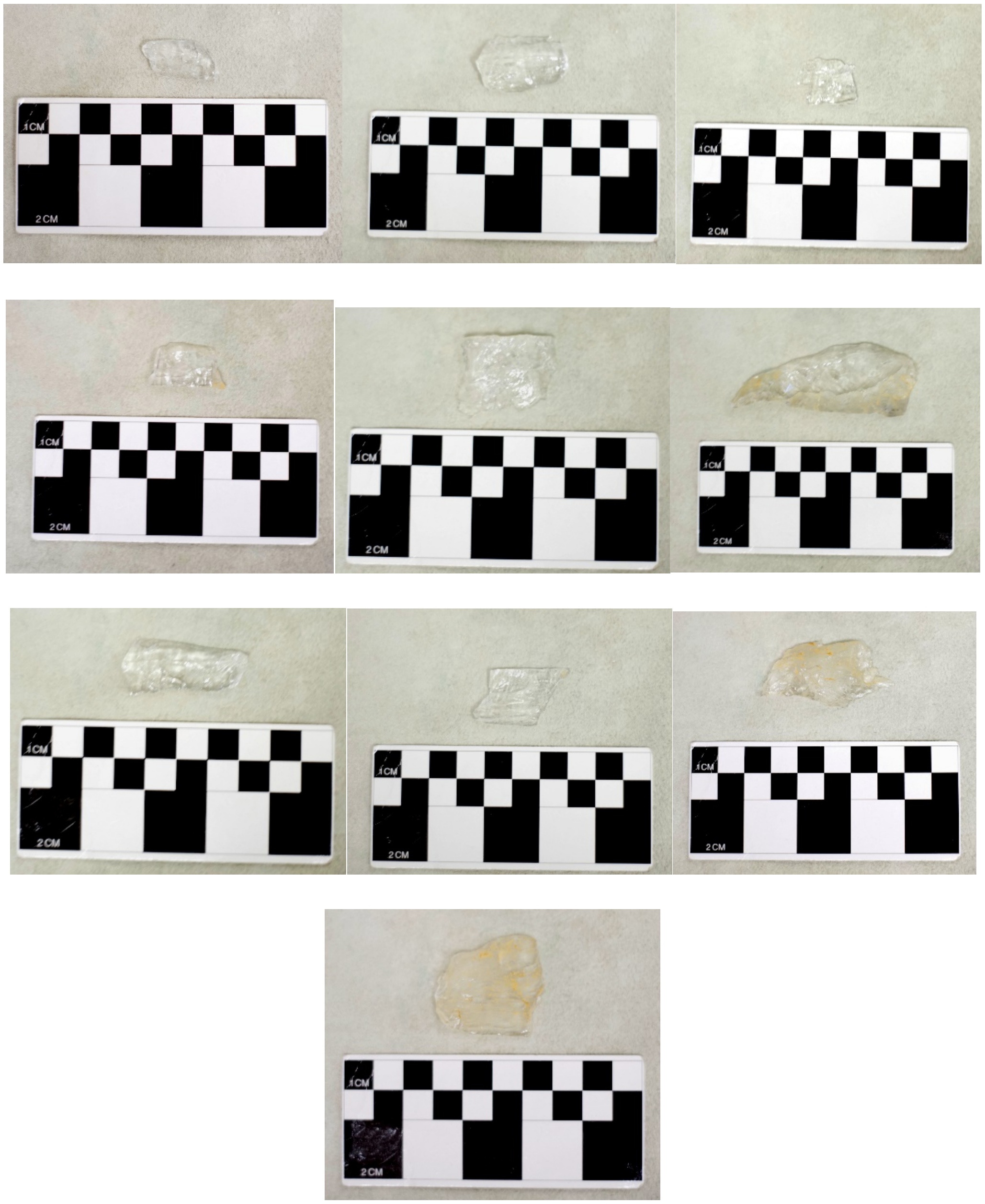

Figure 29. Resulting flakes removed from Stone #2. Scale in cm.

Stones #3, #4 and #5 were used to manufacture projectile points. Strong evidence shows that quartz tips have been fashioned and hafted for use in bow and arrow hunting (Lombard 2011). I have no reason to suspect that the quartz crystal points of this experiment would not be effective at killing game. After the reduction sequence the resulting five projectile points were photographed along with the resulting debitage. Figures 30, 31 and 32 are the points with the resulting debitage. Stone #3 produced three projectile points (Figure 30). Stone #4 produced no projectile points (Figure 31) and only resulted in thick shattered fragments. Stone #5 produced two projectile points (Figure 32). Their physical description are in Table 7.

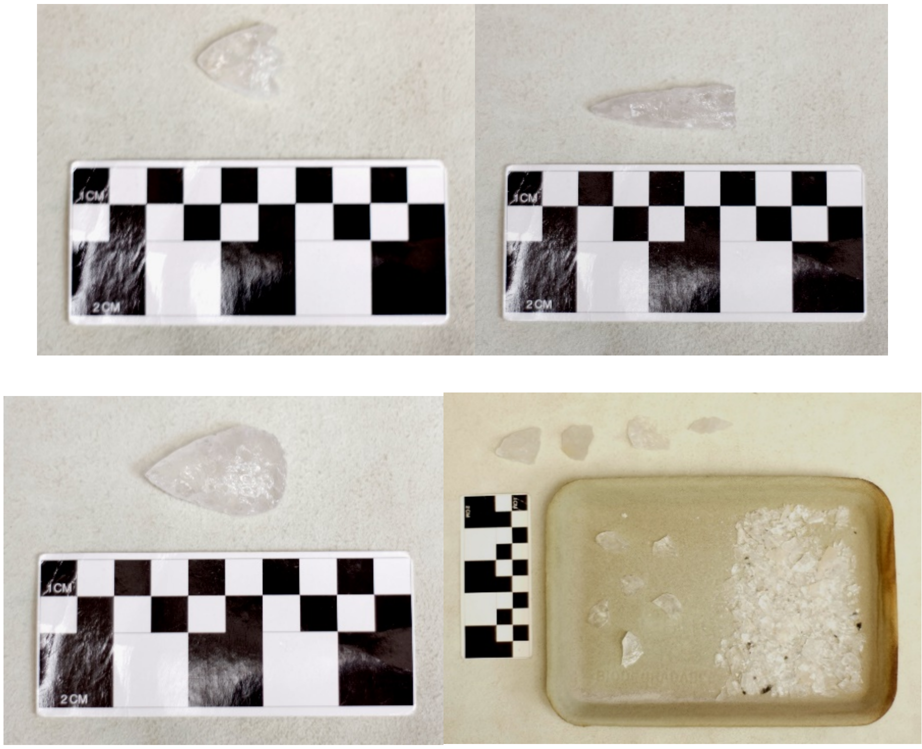

Figure 30. Projectile points and debitage produced from Stone #3. Scale in cm.

Figure 31. Resulting debitage from Stone #4. No projectile points were able to be made. Scale in cm.

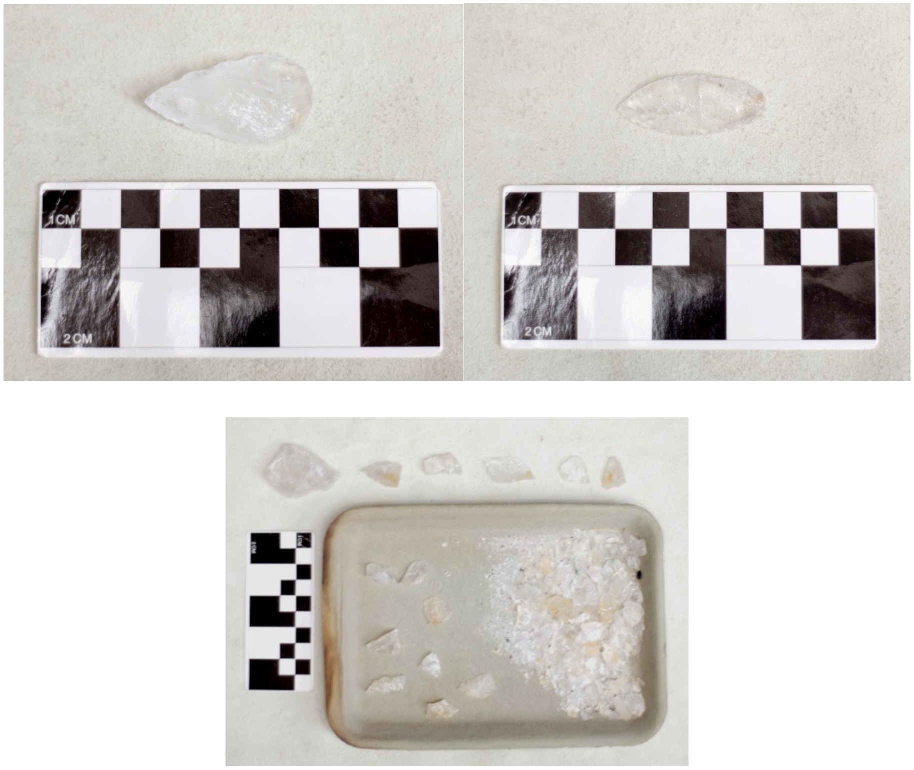

Figure 32. Projectile points and resulting debitage from reduction of Stone #5. Scale in cm.

Stone #	Point #	Length	Width	Thickness	Weight
3	1	24 mm	20 mm	5 mm	2.6 g
	2	42 mm	14 mm	9 mm	4.5 g
	3	40 mm	25 mm	9 mm	8.6 g
4	Na	Na	Na	Na	Na
5	4	43 mm	24 mm	16 mm	9.7 g
	5	42 mm	17 mm	5 mm	4.2 g

Table 7. Projectile point descriptions from reduction of Stones #3, #4, and #5.

Conclusions on the Manufacturing Experiment

As stated by Crabtree earlier, quartz crystal has two huge impediments that kept it from being used widely as a raw lithic material; it is rare and difficult to work with. After working with this material for months I think that Crabtree was correct and his assessment is supported by the limited frequency of quartz crystal tools in the archaeological record. I was however surprised that manufacturing tools from quartz crystals is not beyond the skill of flintknappers but in fact very possible and increases as the purity of the crystal increases. As shown by the consistent distribution of quartz debitage through time at the archaeological sites of Kelly Forks and Weitas Creek, ancient peoples did use quartz crystal presumably to the extent it was available. We can assume that it was sought out as a viable lithic source and that people of the past would have used it when available.

Manufacturing ease was dictated by the characteristics of the crystals, as the purity increased and homogeneity increased and the inclusions decreased the resulting flakes became more predictable. If one were to compare it to cryptocrystalline quartz or obsidian there is a much higher percentage of failure due to unexpected fracturing and crushing. As discussed in Chapter 2 molecular bond arrangement and crystal growth variability are responsible for a majority of unpredictable failures. My experience was that the number of usable flakes from quartz crystal was far less than other lithic materials of choice. The usable flakes were consistently smaller and had many step fractures and crushed edges, and more time and effort was expended to refine tools.

The hardness of the crystal material produced one unexpected result in that broken debris contained many sharp and hard points that would make optimal gravers for engraving bone, wood or other hard materials without much damage to the point of the tool.

CHAPTER 6: USE-WEAR ANALYSIS OF QUARTZ TOOLS

Introduction

Use-wear analysis studies have been performed on quartz crystal material most notably by Sussman and Knutsson (Huang and Knutsson 1995; Knutsson 1988; Sussman 1985, 1988) through the use of both Optical and Scanning Electron Microscopes (SEM). A brief understanding of their results will be beneficial to this study.

Knutsson's model for quartz deformation is based on mechanical abrasiveness and results in micro-pitting, observable as polish (Huang and Knutsson 1995). This is informative for understanding the results of quartz use on high silica materials such as antler, bone and wood. High polish is produced when tools are used in a cutting or abrasive manner but Sussman suggests that the highest levels of polish are observed when working with plant material (Sussman 1985).

Fracturing was the most common result, and is attributed to material weakness. Quartz has a very low tensile and compressive strength leading to visible compression fractures and chipping of edges under magnification. Sussman observed more edge rounding when used in certain tasks such as scraping hides (Sussman 1985). Knutsson observed fractures and striations below the top layer of amorphous silica typical of working with wood (Knutsson 1988), while Sussman found bone and antler left comet-shaped striations on the surface (Sussman 1988).

Some limits are suggested on the ability to perform functional analysis on quartz tools. Quartz can be vulnerable to chemical alteration and thus remove or distort evidence of past use (Marreiros et al. 2015). Evidence suggests that post-depositional alterations must be considered when analyzing use-wear and that some alterations may obliterate any evidences that once existed. At the French site of Payre the entire tool assemblage was examined for use-wear evidence with the use of SEM. The evidences of sawing, scraping and working meat was found on the majority of the assemblage, but very few of the quartz tools had maintained marks from use due to chemical alteration after deposition (Marreiros et al. 2015).

There are four techniques for evaluating use-wear on lithic tools and for more than three decades researchers in use-wear analysis have debated which of the four is most diagnostic. The four main observation techniques are: optical microscope, which includes macro-scope 4-10x, and microscope 10-400x; scanning electron microscope (SEM) and laser scanning confocal microscope (Derndarsky and Ocklind 2001; Lemorini et al. 2014; Marreiros et al. 2015).

The first studies using macroscopic technology later received much criticism as microscope and later techniques were developed. The assumption being that more detail at higher resolutions was better at providing use-wear evidence. Things that had not been visible at macro-scope levels such as polish and micro fracturing became very important to those that believed microscope and SEM levels were the answer to providing absolute answers in use-wear. After years of analysis, micro fractures and polishes have proved to be difficult to decipher even with the best methods and techniques, and most scientist have come to the conclusion that all four techniques are complimentary in correctly evaluating use-wear (Lohse 1996); (Marreiros et al. 2015). This conclusion led me to select the use of a 60x- 250x digital microscope for this analysis.

A mention of the variability between homogeneous and heterogeneous quartz material must be discussed to completely understand the methodology of use-wear analysis on quartz tools. Homogenous materials tend to be composed of one single crystal or a homogenous matrix of material. The surfaces of the tools tend to be smoother and wear in an even fashion. Conversely, heterogeneous crystalline structure doesn’t wear consistently due to variation of the chemical composition affecting hardness. Also when the crystalline structure presents variablity in crystal size the surface will have isolated highpoints that wear at different rates (Marreiros et al. 2015). Established methods dictate that to accurately examine a heterogeneous crystalline structured tool magnifications of 400x or more are necessary. Pure quartz crystal tools are homogeneous crystalline materials and can be properly examined through the use of 40x to 200x optical magnification.

A possible complication became apparent after examining the edges of the blades I had manufactured. Although quartz crystal can fracture conchoidally, a majority of the time it fractures inconsistently. Complications could foreseeably arise in use-wear evaluation of crystal tools due to the unpredictable fracturing caused by oblique growth lines. Unlike other silicates these unpredictable fractures leave edges ragged and rough and this must be taken into account as it may cause variation in tool edge geometry.

Use-wear Analysis Methods

The following section delineates the steps that were used in this experiment and protocol for analysis.

Ten materials were selected as the antagonist to the cutting edges. Two tools were assigned to each of the preceding materials, one to cut and one to scrape. Cut is defined as:

the tool being run along the cutting edge against the surface of the material, cutting edge down being drawn along its axis. Scrape is defined as: the tool contacting the surface edge down at less than 90 degrees of angle, the tool being drawn not with the edge axis but perpendicular to its length.

Each tool performed the motion being in contact with the antagonist material one hundred times with reasonable pressure. The objective of the motion was to cut or scrape that antagonist material and not with intention to alter the tool.

Photos were taken pre-use at 60x and post-use at 60x and 250x with a digital microscope. The scope used in the experiment is the 60x/ 250 Digital Microscope manufactured by the Monoprice Corporation. A comparison of the before and after photos was made to determine any alteration of the tools. The results were recorded in Table 8 below.

Tool #	Antagonist	Type	Motion	Edge result
1	Hide	Bovine	Cut	Minimal, conchoidal fractures
2	Hide	Bovine	Scrape	Small scaler fractures
3	Sinew	Bovine	Cut	Conchoidal and crushing fractures
4	Sinew	Bovine	Scrape	Heavy edge beveling
5	Bone	Bovine	Cut	Heavy crush fractures
6	Bone	Bovine	Scrape	Heavy beveling and rounding
7	Bone	Rabbit	Cut	Heavy conchoidal fracturing
8	Bone	Rabbit	Scrape	Edge rounding and crushing fractures
9	Wood	Larch	Cut	Edge rounding, conchoidal fracture
10	Wood	Larch	Scrape	Edge polishing, conchoidal fracture
11	Wood	Fir	Cut	Edge beveling, polishing
12	Wood	Fir	Scrape	Deep beveling and polishing
13	Reed	Tule	Cut	Light conchoidal fracture
14	Reed	Tule	Scrape	Edge beveling
15	Grass	Bunch Grass	Cut	Tiny conchoidal fractures
16	Grass	Bunch Grass	Scrape	Light edge beveling
17	Flesh	Deer	Cut	Tiny conchoidal fractures
18	Flesh	Deer	Scrape	Almost no damage, Small scaler fractures
19	Flesh	Salmon	Cut	Almost no damage, tiny conchoidal fractures
20	Flesh	Salmon	Scrape	Almost no damage, small scaler fractures

Table 8. Results of quartz tool usage according to material used on and movement with use.

Use-wear Analysis Results

The following figures 33 to 52 are the results of the use-wear analysis. All twenty tools were photographed next to a cm scale. The pre-use edge was photographed at 60x magnification. The tool was used for its designated cutting or scraping task on the material it was assigned to and then the edge was again photographed, first at 60x magnification and then at 250x magnification.

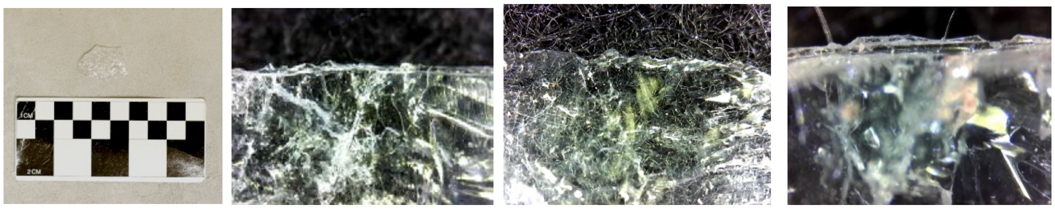

Figure 33. Tool one, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on dry boving hide. The result was very little edge alteration, with small conchoidal fractures close to the edge.

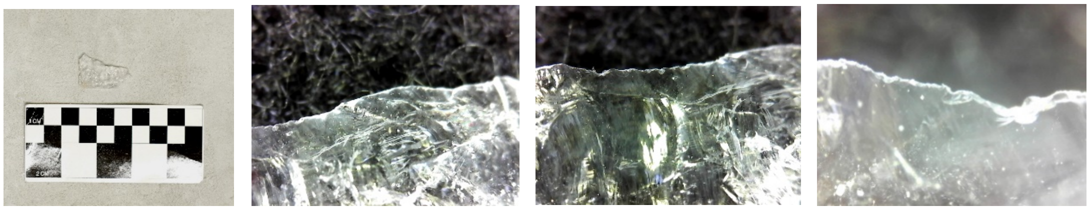

Figure 34. Tool two, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on dry boving hide. The result was very little edge alteration, with small scaler fractures on the opposite side of contact, running the entire length of the blade.

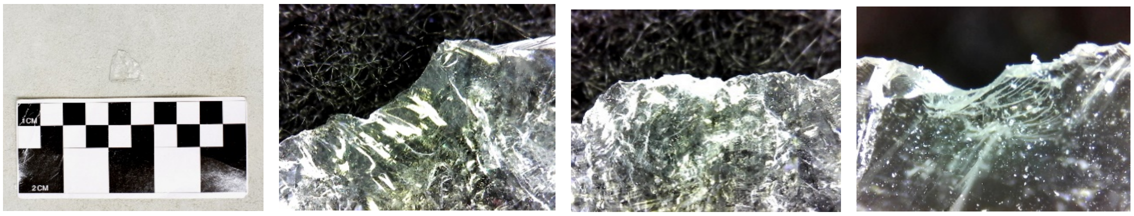

Figure 35. Tool three, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on dry boving sinew. The result was deep conchoidal fracturing and edge crushing.

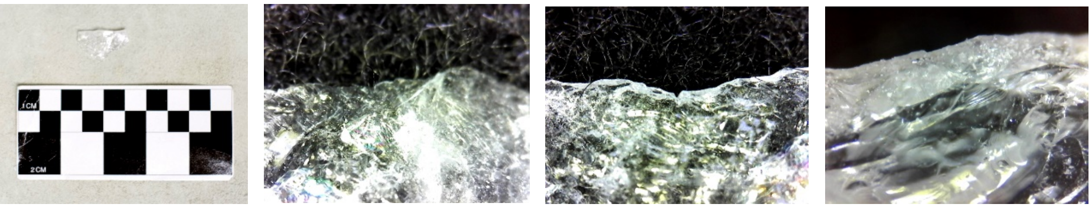

Figure 36. Tool four, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on dry boving sinew. The result was edge crushing and heavy beveling.

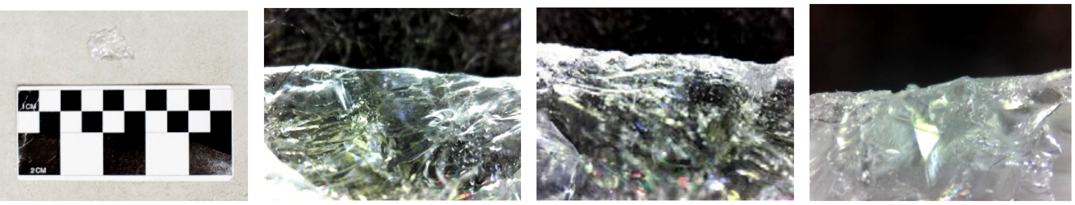

Figure 37. Tool five, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on green boving bone. The result was heavy edge crushing, flattening, and conchoidal fracturing.

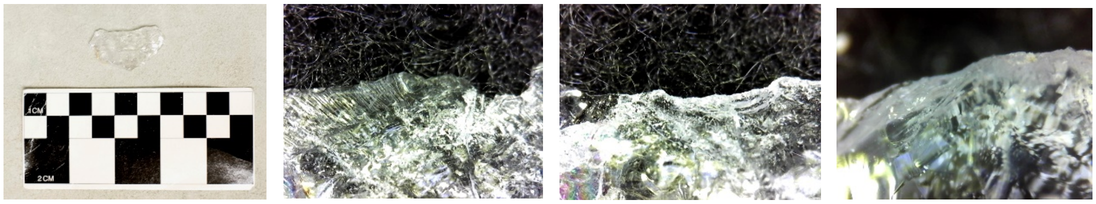

Figure 38. Tool six, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scrapping strokes on green boving bone. The result was heavy beveling, and edge rounding.

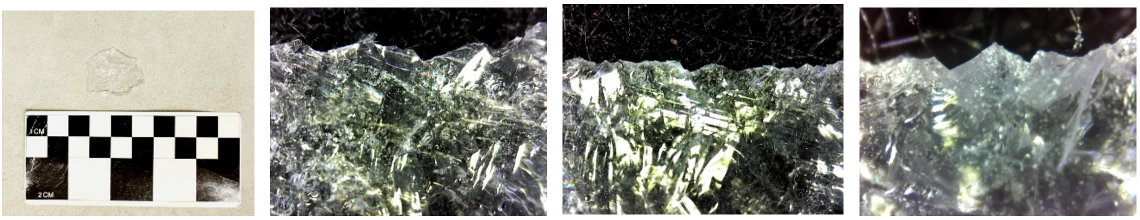

Figure 39. Tool seven, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on green rabbit bone. The result was heavy conchoidal fracturing.

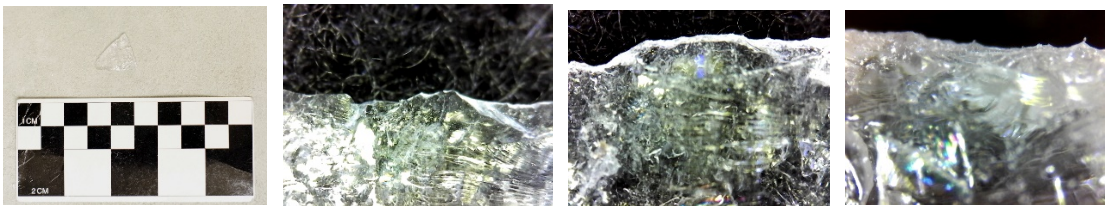

Figure 40. Tool eight, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on green rabbit bone. The result was heavy rounding and edge crushing.

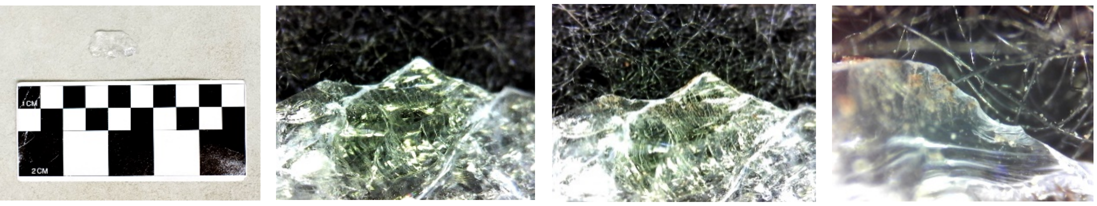

Figure 41. Tool nine, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cuting strokes on dry larch wood. The result was crush fracturing and some edge rounding.

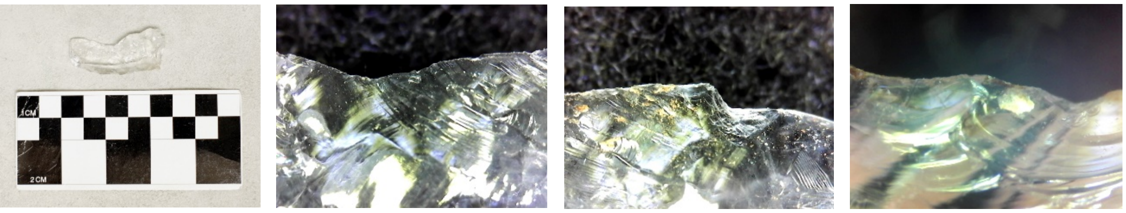

Figure 42. Tool ten, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on dry larch wood. The result was conchoidal fracturing and edge rounding.

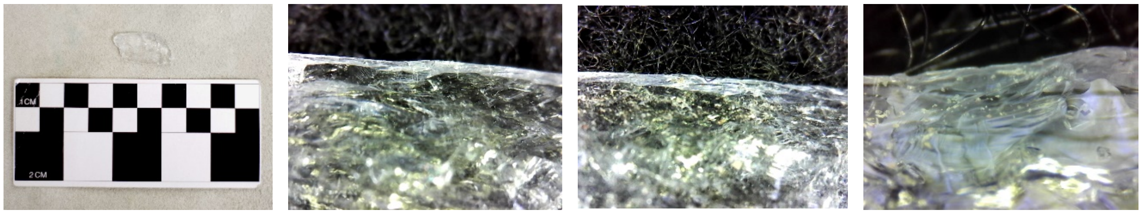

Figure 43. Tool eleven, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on dry fir wood. The result was very little fracturing with some beveling and polishing.

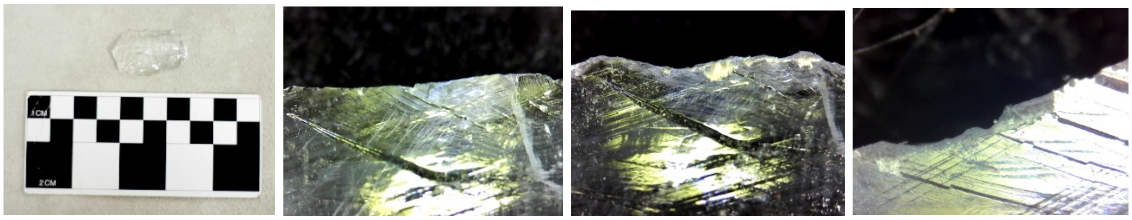

Figure 44. Tool twelve, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on dry fir wood. The result was heavy beveling and crushing with no conchoidal fracturing.

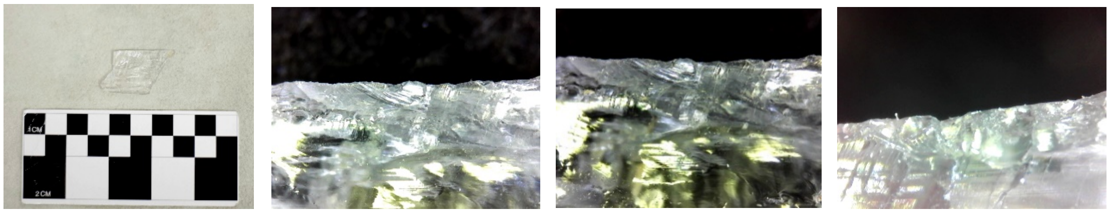

Figure 45. Tool thirteen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on tule stock. The result was light conchoidal fracturing.

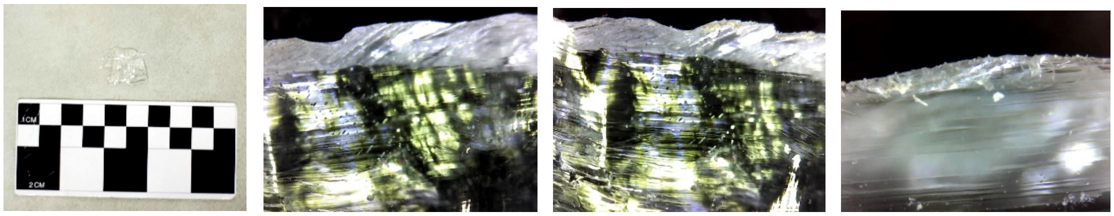

Figure 46. Tool fourteen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on tule stock. The result was smooth edge beveling.

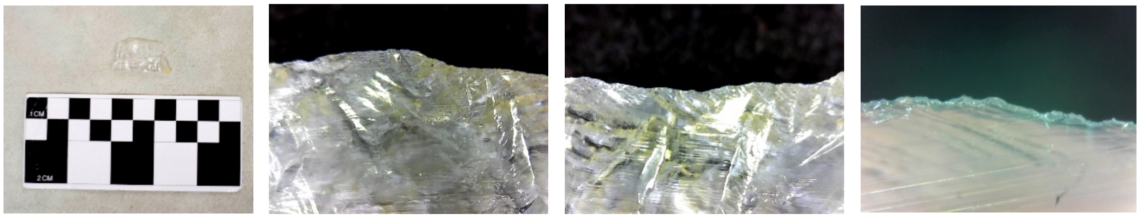

Figure 47. Tool fifteen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on bunch grass. The result was light conchoidal fracturing.

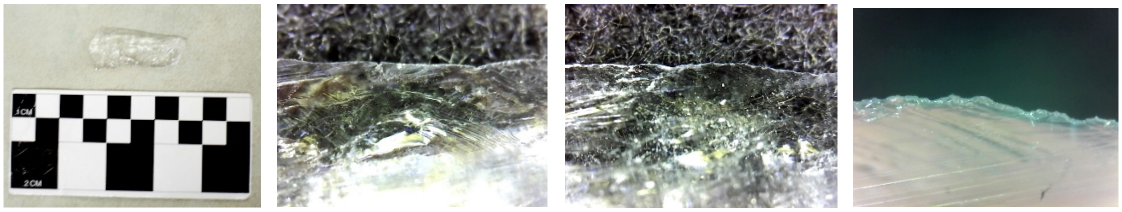

Figure 48. Tool sixteen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on bunch grass. The result was light edge beveling.

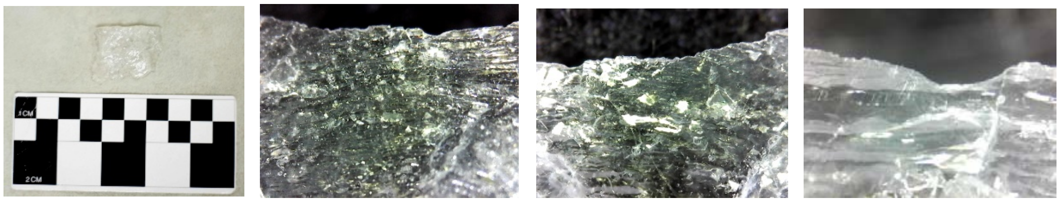

Figure 49. Tool seventeen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on raw deer meat. The result was very minimal conchoidal fracturing.

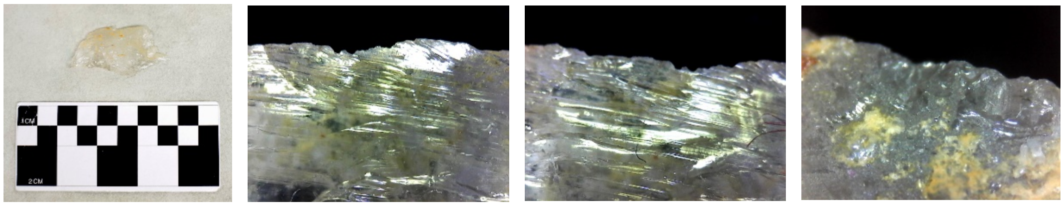

Figure 50. Tool eighteen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on raw deer meat. The result was light scaler fractures on the opposite side of contact.

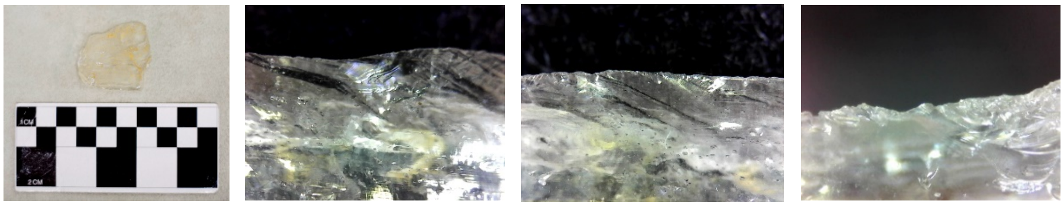

Figure 51. Tool nineteen, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 cutting strokes on raw salmon meat. The result was minor conchoidal fracturing.

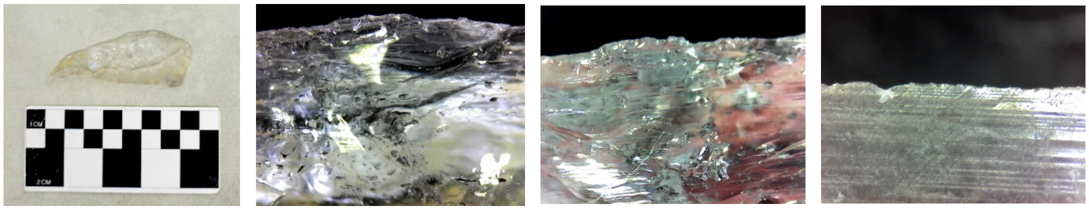

Figure 52. Tool ten, edge at 60x before task, edge at 60x and 250x after task. The tool made 100 scraping strokes on raw salmon meat. The result was light scaler scars on opposite side of contact.

Conclusions

The experiment results were viewed with 60x and 250x optical magnification. This method proved to be valuable at observing how using the tools altered the edges. A couple of consistencies were observed and are worth noting.

Cutting consistently produced conchoidal fracturing and/ or crushing. The softer materials such as deer and salmon meat produced small, almost unobservable conchoidal fractures even at 250x. Damage was so minimal that the tools could have performed the 100 stroke cutting task many times over with perfect efficacy. As the materials tested became harder, conchoidal fracturing on the tools increased, resulting in a very jagged vertical edge as well as the appearance of crush fractures. Green bone of both species tested resulted in the most crush fractures. The harder plant materials, fir and larch, produced crush fractures along with a small amount of polishing.

Scraping consistently produced small pressure flakes on the opposite side of the edge contact. Most of these pressure flakes were half moon shaped and not deep. Many terminated in step fracturing and did not leave the edge jagged. These flakes must be differentiated from conchoidal fractures caused by direct verticle pressure on the edge that resulted in much deeper and feathering terminations. Beveling was a consistent result of scraping on any of the test materials, with the most pronounced on the harder materials: larch, fir and bone. At 250x some polishing could be observed on tools that were used to scrape fir and larch.

Material hardness consistently produced more dramatic observable effects. The soft materials, such as flesh, hide and grass, had minimal effects on the tool edges under the 100 stroke test, while the harder materials, such as wood and bone, consistently dulled the tools more. Although the tools used on wood and bone were dulled to some degree after 100 strokes, the tools still had cutting ability and could have been used for other cutting tasks.

Overall, I was surprised at the ability of the tools to maintain sharp edges. Although the initial sharpness may not be that of other silica tools, I think that after having used quartz crystal personally it is very apt at performing cutting tasks and its hardness lends itself to longevity.

CHAPTER 7: CULTURAL CONSIDERATIONS

Philosophical Direction of Archaeology

The research performed in this thesis has been scientific in its philosophical thrust. The use of objective observation and empirical data collection through the scientific method gives us great insight into the natural processes that result in the world around us.

A backlash against the pretenses of processual archaeology in the recent past has opened an avenue for the interpretation of ritual, symbolism and belief. Whitley et al. 1999 concluded that the problem with interpretation of ancient religion is an effect of processual archaeology's adherence to its behaviorist roots that deny ontological pluralism, maintaining the stance that non-material phenomena cannot have material consequences (Gardner 1985). This philosophical view can easily be overcome if one considers that religious behavior leaves material evidence. Examples are numerous such as, temple structures, rock art and ceremonial objects (Whitley et al. 1999). Many studies such as those of Crocker (1985) and Wilber (1987) show that ritual and ceremony have origins in natural phenomena. Rather than being an irrational system of belief or physiological impulses, ceremony and ritual are logical observations of ecological systems and phenomena.

Evidence from sites in the Clearwater Basin suggests that people collected and curated unaltered quartz crystals along with crystal tools (Longstaff 2013). The sites of Arrow Beach, Weitas Creek and Kelly Forks all contained fully-faceted quartz crystals that had been intentionally brought to the locations. I believe that it is fair to question if ancient peoples valued quartz crystals beyond a limited utilitarian use.

The presence of unaltered crystals suggests that if nothing else, the material had enough interest for a person to carry it home. One specific case of such a crystal, that warrants mention, was found at the Kelly Forks site. A quartz crystal faceted point was discovered next to an unidentified metallic material (Fig. 53). These rare materials lying near each other in the same level of deposition could suggest that both items were curated for reasons that may have been spiritual or cultural. It is intriguing to consider that perhaps these two items were carried by someone because of their uniqueness and perhaps the person collected these two items for cultural or spiritual reasons (Longstaff Personal Communication 2015).

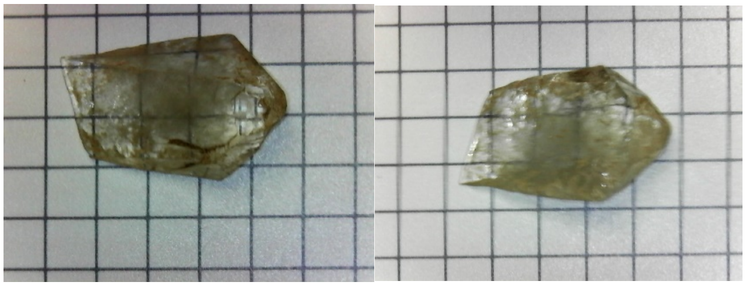

Figure 53. Faceted quartz crystal found on the same level and proximal to the metalic object in Figure 54.

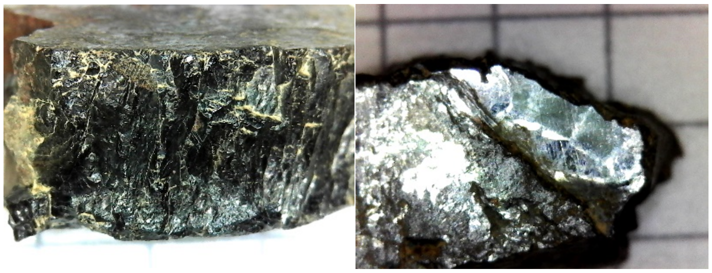

Figure 54. Unknown metallic object found on the same level and proximal to the faceted quartz crystal of Figure 53.

It is easy to assume that the visual clarity and rarity of quartz crystal would have given it value beyond a simple material that could be altered to cut and chop. Other examples of the use of quartz crystal exist outside of the Clearwater Basin and after researching this topic I think it would add to this thesis and perhaps broaden the topic to include some examples where the crystals were used other than for reasons of expediency.

Simon Clovis Cache

The Simon Clovis cache from South-Central Idaho contains four very unique biface points made from quartz crystal. The site is located near Fairfield, Idaho, on the bank of Deer Creek. Analysis of the tools paints interesting images of the collection and perhaps the purpose of the cache. The entire cache to date consists of 32 biface tools, 4 of which are made from quartz crystal (Kohntopp 2010). All the 32 points found in the Simon Clovis cache were of silica material and not native to the surrounding area. All the materials of the cache are not local to Fairfield, and the materials that have been sourced show that the tools would have been transported an average distance of 682.5 km before deposition. This makes the Simon Cache the most diverse material assemblage ever found in a Clovis site (Kohntopp 2010). This diverse assemblage and long distance of travel to procure material raises a lot of questions that may not be able to be answered, but some commonalities in other Clovis sites can be observed.

Clovis assemblages can be broken into two types of deposits: utilitarian and ritual. Utilitarian caches tend to be associated with butcher or kill sites and contain fragments of tool debitage and faunal remains. Swanson and Butler concluded at the end of the excavation at the Simon site that it was neither a butchering site nor a kill site but rather a camp site due to the lack of both lithic debitage and faunal remains (Kohntopp 2010). The deposit of so many unbroken and unfinished tools with no clear reason for utilitarian use suggests that the deposit at the Simon site was a ritual deposit. In addition, the diversity of the materials and the distances from parent sources of stone strongly suggests that the tools were most likely deposited for a ritual purpose. Bolstering this hypothesis is the proximity of quality knappable obsidian stone sources. Sources of obsidian lie little more than a day's journey on foot from the site's location, but none of the tools are made from that obsidian (Kohntopp 2010).

Kohntopp and others have speculated that the source of the raw quartz crystal that makes up the four crystal points may have been found nearby in the Idaho Batholith. Within one hundred miles of the Simon cache are multiple sources of quartz material that could match the quartz bifaces of the cache, one at Atlanta, Idaho, and the other at Trinity Mountain, Idaho. A crystal of this size would have been difficult to procure and with certainty would have been precious to an ancient toolmaker.

The quartz bifaces are extremely clear and would have been attractive. Quartz crystal also has the ability to luminesce when rubbed together. Without knowledge of molecular bonding, this amazing sight may have been seen as magical, giving the material a high perceived or ritual value over its utilitarian value.

It is also speculated that the Simon site could have been a burial site. Many published opinions suggest that Clovis tools recovered from mortuary sites have large blade sizes versus those that were utilitarian. Unfinished blanks would have been left to the dead for hunting in the afterlife (Kohntopp 2010). Only five of the points were finished, supporting the speculation that the Simon Clovis points were fabricated and left for ritual reasons rather than utilitarian use.

Kohntopp and others have also proposed the deposit was a votive site similar to the East Wenatchee site which was thought to have been deposited as an offering to avert the destruction by local volcanic activity. Like the Wenatchee site, the Simon site lies near a volcanic area. A mere 34 miles south of the Simon site is Black Butte, which according to geologists, would have erupted contemporaneously with the deposition of the cache.

Interestingly, all four bifaces are in the first stages of reduction and are not refined and not fluted as are most of the points from the site. This may imply that the manufacturer intended to leave the tools as blanks for ritual reason or perhaps the prospect of breaking the bifaces was too intimidating.

Sally's Rock Shelter

Sally's Rock Shelter located in the Mojave Desert of California provides more evidence of quartz being used for ritual or spiritual purposes. The site is a shamanistic location where rock petroglyphs are abundant. These petroglyphs are associated with quartz lithic scatters and cobbles that can be directly related to the making of the rock art. The cobbles were found wedged into the cracks of the large boulders of the rock shelter. These cobbles were unmodified and speculation is that they were votive offerings.

Analysis of the rock art has shown that the engravings and peck marks that left quartz residue in the fissures and on the surface were created in ritual and or ceremony. This is supported by the wide association of shamans and vision quests with supernatural power and quartz (Whitley et al. 1999).

Tribo-luminescence, a glow produced as quartz is broken or rubbed together was observed by ancient people and could have supported the belief that the rocks contained power (Whitley et al. 1999). This belief in essence would have been a result of careful observation of natural phenomenon, and in a practical sense was correct, the rocks do contain power that is released when the rock is abraded. If ancient belief that quartz had shamanistic power was based on an actual natural observation, the belief that the power of the rocks could be used in ritual to enhance a shaman's power is evidence of its cultural importance (Whitley et al. 1999).

As framed by Descartes, western positivism is based in logic and maintains that science is rational, while ritual, belief and ceremony systems are irrational and illogical (Whitley et al. 1999). This has supported the philosophical thrust of processualists, that prehistoric spiritual beliefs are irrelevant and cryptic because they cannot be reconstructed. I think, that through examination of quartz in the archaeological record and its relation to shamanistic practice, we can see at least that belief systems were being logically and coherently based on naturally observable phenomenon, and that phenomenon was instrumental in the function and construction of those cultural systems.

CHAPTER 8: POTENTIAL FOR FUTURE RESEARCH

Research into ancient use of quartz crystal could be continued along two separate paths, one scientific and the other interpretive. The scientific data collected in this thesis barely scratched the surface while the use-wear analysis and manufacturing portion of the research were limited by both time and resources and could be extended. The quantity of tools replicated and the cutting tasks performed with those tools could be augmented to provide a better understanding of the types of wear a quartz crystal tool undergoes when in use. The limited observation performed only with a digital microscope could also be expanded to include the use of macroscopic observation, SEM, and laser scanning confocal scopes. Last, the data of known sites containing quartz crystal artifacts in Idaho should be compiled to expand the understanding of its use on a regional scale.

Beyond the scientific, processual-driven research, a more exciting path of research awaits in the interpretation of quartz crystal association with ritual and belief. As was demonstrated in this thesis, western philosophical thought has limited archaeological analysis to mostly scientific data, almost completely ignoring and devaluing the more ethereal understanding of material use. My personal conviction is that the objects of archaeology are only important as far as they help us to understand the behavior of people that interacted with them. Understanding the ways they lived and their beliefs that created their reality, a different reality than we currently travel, holds more value than the long dead items recovered from the dirt.

Further research into this realm of ritual, ceremony and beliefs could shed light on many of the practices that allowed prehistoric peoples to live in harmony with their surroundings. This traditional knowledge could prove invaluable to some of the exigent problems of our society and interactions with the natural world. The objective reality we live in established by philosophers such as Descartes has evolved into a system that suffers from a lack of valuing other realities and other systems of knowing the world.

A continuation of research on this topic would be directed at belief, ritual and ceremony and the liminal states of other realities such as the vision quest with its association to quartz crystal. Now that it has been established that quartz crystal held value beyond expediency for lithic tools, the next step for archaeology is to validate the knowledge that indigenous peoples understood for thousands of years about quartz and how they were able to interact with it through their belief systems.

CHAPTER 9: SUMMARY AND CONCLUSIONS

Summary

Quartz crystal is a rare and unique mineral in the world and its use in the Clearwater River Basin of Idaho has provided an opportunity to gather data and explore its use and value to ancient peoples. An understanding of its molecular properties and its formation are necessary if we wish to know why people would have taken the effort to collect and curate it. Regional geology shows that the Idaho Batholith formation's intrusion into the much older Belt Supergroup contributed to the occurrence of sources of quartz crystal in the region. Although sourcing of the tools found at Kelly Forks and Weitas Creek has not yet been completed, with the discovery of more potential sources we come closer to knowing where the raw materials may have been procured.

The quantity of quartz crystal lithic tools and debitage is a minute portion of the overall lithic collections of the area, regardless the material was used and is found in greater quantities as one travels up the North Fork of the Clearwater River. Examination of the tools and debitage shows that most were small single edge tools and few in number.

We know with certainty that the ancient people of the Clearwater River were collecting and using quartz crystal as far back as 13,000 years ago, for cutting tools. Evidence suggests that people also collected fully-faceted crystals for reasons other than utilitarian purposes (Longstaff 2013; Longstaff Personal Communication 2015).

By performing both a use-wear analysis and experimental manufacture of quartz crystal lithic tools, I hoped to provide practical hands on experience that can be used to analyze future finds. The workability of the stone was in line with Crabtree's assessment noting the difficulties and unpredictability of the material. The utility of quartz crystal blades was surprising and the material proved to be extremely effective at cutting tasks and durable throughout the process.

Cultural considerations and past use of quartz by ancient peoples for reasons other than expedient cutting tasks has received the least amount of attention by past and current archaeologists. Reference to the sites of Sally’s Rock Shelter and the Simon Cache are only two examples that could support further lines of research into the study of prehistoric belief systems.

Conclusions

In this work I set out to understand quartz crystal tool usage in the Clearwater River Basin. My research rapidly expanded to include chemical information on the material itself. I recognized the value of understanding the molecular arrangement of quartz and how that is different than other silicate forms. This slight difference is created by the formation process in pegmatites on fault zones in conjunction with pluton magma pooling. This unique set of formation criteria makes quartz crystal rare in geologic terms and is reflected in the archaeological record. This understanding supports the conclusion that ancient peoples used quartz crystal when it was available, which was rare. Sources in the Clearwater Basin are remote which would have made the raw material more difficult to obtain.

After hours spent manufacturing and testing lithic tools made of quartz crystal, I think that the material is difficult to work with. The largest problem is unexpected fracturing caused by unseen growth lines created during the formation of the crystal. The cleaner and more complete the crystal formation the easier it seems to work and is to predict. I am convinced that if large, fully-faceted crystals with few inclusions were available, a skilled flintknapper ancient or modern, could fabricate large, sharp, cutting tools consistently. These tools proved to be very effective at cutting tasks I performed and they exceeded my expectations of their efficacy and durability, maintaining sharp edges through cutting and scraping. Based on this information I think that ancient peoples would have used quartz crystals for cutting tools when the material was available.

Understanding that the methods and theories of a positivist system dictate that research and analysis be conducted within certain parameters, I think that archaeological research can be effectively performed while questioning behavior that is non-materialist in nature. Religion, ceremony, and ritual have been discounted due to intangibility, but it should be recognized that clues and suggestions of its existence are woven through the material culture of the past. The interpretive analysis of the religious use of quartz has been limited, but there is great potential for future research. Correct interpretation of such phenomenon cannot be guaranteed, but we must recognize to some degree that all interpretation is subject to error, bias and subjectivity. This is not an excuse to allow for unfounded conclusions based in modern paradigms, but rather that we make room to interpret the non-material culture of the past recognizing that religious behaviors were not irrational in nature but based on thousands of years of observation of natural phenomena.

REFERENCES

Bertalaffny, L. V.

1950 Outline of general systems theory. *British Journal of Philosophy of Science* 1: 1-10

Breiter, Karel, Lukas Ackerman, Martin Svojtka, and Axel Muller

2013 Behavior of trace elements in quartz from plutons of different geochemical signature: A case study from the Bohemian Massif, Czech Republic. *Lithos* 175-176, 54-67

Bruggencate, R.E. ten, Mostafa Fayek, Kevin Brownlee, Brooke Milne, and Scott Hamilton

2013 A combined visual-geochemical approach to establish provenance for pegmatite quartz artifacts. *Journal of Archaeological Science.* 40: 2702-2712

Crabtree, D. E.

1975 Comments on lithic technology and experimental archaeology. *Lithic Technology* E. Swanson (Editor) pp. 105-114. Aldine, Chicago.

Cristina, Lemorini, Thomas W. Plummer, David Braun, Alyssa N. Crittenden, Peter W. Ditchfiled, Laura C. Bishop, Fritz Hertel, James S. Oliver, Frank W. Marlow, Margaret J. Schoeninger, and Richard Potts

2014 Old stones' song: Use-wear experiments and analysis of the Oldowan quartz and quartzite assemblage from Kanjera South (Kenya). *Journal of Human Evolution* 72: 10-25.

Derndarsky, Monika, and Goran Ocklind

2001 Some Preliminary Observations on Subsurface Damage on Experimental and Archaeologial Quartz Tools using CLSM and Dye. *Journal of Archaeological Science* 28: 1149-1158

Driscoll, Killian

2011 Vein quartz in lithic traditions: an analysis based on experimental archaeology. *Journal of Archaeological Science* 38: 734-745

Flenniken, J. Jeffrey

1981 *Replicative Systems Analysis: A Model Applied to the Vein Quartz Artifacts from the Hoko River Site*. Washington State University Laboratory of Anthropology Reports series No. 59

Hurlbut, Cornelius S.

1970 *Minerals and Man*. Random House. New York, NY.

Idaho Geographic Survey
2015 Geographic Map Database. Taken from: http://www.idahogeology.org/webmap/

Idaho State University
2015 Geologic Mining Map Database. Taken from: http://imnh.isu.edu/digitalatlas/geog/mining/minefr.htm

Johnson, L. L.
1978 A history of flint-knapping experimentation, 1839-1976. *Current Anthropology* 19: 337-373.

Keeler, Robert W.
1973 *An Upland Hunting Camp on the North Fork of the Clearwater River: North-Central Idaho.* Occasional Papers of the Museum: Number 30 Idaho State University, Pocatello.

Kohntopp, Steve W.
2010 *The Simon Clovis Cache: one of the oldest archaeological sites in Idaho.* Center for the study of the First Americans, Texas A&M University, Topps Printing. Bryan, Texas.

Knutsson, K.
1988 Patterns of tool use: Scanning electron microscopy of experimental quartz tools. Aun 10. *Societas Archaeologica Upsaliensis*, Uppsala.

Lohse, E. S.
1996 A computerized Descriptive Systems for Functional Analysis of Stone Tools. *Tebiwa* Vol. 26 (1)

Lombard, Marlize
2011Quartz tipped arrows older than 60 ka: further use-trace evidence from Sibudu KwaZulu-Natal, South Africa. *Journal of Archaeological Science* 38:1918-1930.

Longstaff, Laura
2013 Archaeological Investigations at the Kelly Forks Work Center Site (10CW34): Clearwater River National Forest, North Central Idaho. Master’s Thesis, Department of Anthropology, University of Idaho, Moscow. University Library Online.

Longstaff, Laura
2015 Personal Communication with the author.

Mattson, Daniel M.
1983 *Cultural Resource Investigation of the Dworshak Reservoir Project, North Fork Clearwater River, Northern Idaho.* University of Idaho Anthropological Research Manuscript Series, No. 74, Moscow.

Marreiros, Joao M., Juan F. and Gibaja, Nuno F. Bicho (Editors)
2015 *Use-Wear and Residue Analysis in Archaeology*. Springer New York, NY.

Petr, Gradas, Milan Novak, Jan Filip, and Michaela Vasinova Galiova
2012 *Compositional Evolution of Zoned Tourmaline Crystals from Pockets in Common Pegmatites of the Moldanubian Zone, Czech,* Can Mineral *vol. 50 no. 4895-912*

Quartzpage
2015 Quartz informational web site. Retrieved from: http://www.quartzpage.de/

Ribbe, Paul H. (Editor)
1994 *Silica: Physical Behavior, Geochemistry and Materials Applications*. Mineralogical Society of America. Bookcrafters. Chelsea, Michigan.

Roberts, Willard Lincoln, Thomas J. Campbell, and George Robert Rapp Jr.
1990 *Encyclopedia of Minerals*. 2nd edition, Van Nostrand Reinhold, New York.

Sappington, R. Lee
1988 *Archaeological Test Excavation and Evaluation of the Proposed Clearwater Fish Hatchery Site (10-CW-4), On the North Fork of the Clearwater River, North Central Idaho*. University of Idaho Anthropological Reports, No. 88 Moscow.

Sappington, R. Lee
1996 *Clearwater River Region.* Northwest Anthropological Research Notes. Vol. 30 (1&2) Ken Reid (Editor) pages 117-165.

Sappington, R. Lee
2015 Personal Communication with the author.

Sportsman Review
2015 Sportsman's Digital Publication Taken from: http://m.spokesman.com/stories/1995/dec/02/mud-closes-panhandle-forest-roads-slide-causes/

Stoll, W. C.
1950 *Mica and Beryl Pegmatites in Idaho and Montana Geological Survey Professional Paper,* page 229. United States Government Printing Office, Washington.

Sussman, C.
1985 Microwear on Quartz: Fact or Fiction? *World Archaeology 17*(1), 101-111.

Sussman, C.
1988 A microscopic analysis of use-wear polish formation on experimental quartz tools (Vol 395). Oxford: BAR International Series.

Tallavaara, Miikka, Mikael A. Manninen, Esa Hertell, and Tuija Rankama
2010 How flakes shatter: a critical evaluation of quartz fracture analysis. *Journal of Archaeological Science*. 37: 2442-2448

Toups, Polly A.
1969 *The Early Prehistory of the Clearwater Valley, North Central Idaho*. A Dissertation Submitted to the Faculty of the Department of Anthropology, Tulane University. New Orleans, LA.

Whitley, David S., Ronald I. Dorn, Joseph M. Simon, Robert Rechtman, and Tamara Whitley
1999 *Sally's Rockshelter and the Archaeology of Vision Quest.* Cambridge Archaeological Journal, 9: 2, 221-47.

Whittaker, John C.
1994 *Flintknapping: making and understanding stone tools*. University of Texas Press. Austin,Texas.