Spring 2015

Quartz Crystal Microblade Function in the Salish Sea Region of Washington State During the Locarno Beach Phase (3500-2400 BP)

Rachael N. Kannegaard
Western Washington University, rachael.kannegaard@gmail.com

Recommended Citation

Kannegaard, Rachael N., "Quartz Crystal Microblade Function in the Salish Sea Region of Washington State During the Locarno Beach Phase (3500-2400 BP)" (2015). *WWU Graduate School Collection*. 412.
https://cedar.wwu.edu/wwuet/412

QUARTZ CRYSTAL MICROBLADE FUNCTION IN THE SALISH SEA REGION OF WASHINGTON STATE DURING THE LOCARNO BEACH PHASE (3500-2400 BP)

By

Rachael Kannegaard

Accepted in Partial Completion
of the Requirements for the Degree
Master of Arts

Kathleen L. Kitto, Dean of the Graduate School

Advisory Committee

Chair, Dr. Sarah K. Campbell

Dr. Todd A. Koetje

Dr. Daniel L. Boxberger

MASTER'S THESIS

Rachael Kannegaard

May 11, 2015

QUARTZ CRYSTAL MICROBLADE FUNCTION IN THE SALISH SEA REGION OF WASHINGTON STATE DURING THE LOCARNO BEACH PHASE (3500-2400 BP)

A Thesis
Presented to
The Faculty of
Western Washington University

In Partial Fulfillment
Of the Requirements for the Degree
Master of Arts

By
Rachael Kannegaard
May 15, 2015

Abstract

Quartz crystal microblades are a small lithic tool technology dating predominantly to the Locarno Beach Phase (3500-2400 BP) in the Salish Sea region. The function of these tools has not been well established in previous research. This thesis applies morphological, microwear, and residue analyses to a sample assemblage of 68 quartz crystal artifacts from six archaeological sites in northwestern Washington State (45SK46, 45WH1, 45WH17, 45WH47, 45WH55, and 45WH59). The results of these methods determined that quartz crystal microblades were multiuse tools. Morphological analysis determined the variability of object types and metric measurements within the assemblage. Microwear analyses at multiple magnification levels identified a variety of scar types and patterns which suggests that these tools were likely utilized in both end and side-hafts, but were more commonly side-hafted. Results of residue analyses utilizing the cross-over immuno-electrophoresis (CIEP) method determined quartz crystal microblades were used to process rabbit, deer, and salmon. The use of CIEP analysis also identified human proteins, while the use of a scanning electron microscope equipped with an energy dispersive x-ray spectrometer (SEM-EDX) identified red ochre. The combination of human protein with red ochre suggests that this lithic technology may have also served a ceremonial purpose.

Acknowledgements

First, I would like to thank my wonderful committee. Dr. Sarah Campbell, Dr. Todd Koetje, and Dr. Daniel Boxberger, your advice and support throughout my graduate experience has allowed me to achieve more than I had ever originally planned. Because of you, I will have an always-growing passion for our field. I am also grateful for the Fund of the Enhancement of Graduate Research for the support of my CIEP residue analysis and the Charlton Family Endowment for providing me funding for the first radiometric date for site 45WH59. Thank you to Dr. Robert Yohe for allowing me to assist in the CIEP analysis and for analyzing my samples at a student rate. Thanks also to Carrie Stephens and Sarah from CSUBLAS for their patience and hard work. I owe thanks to Peter Thut, Charles Wandler, and Erin Macri, and the help and resources made available to me by the Anthropology, Biology, and Geology departments, and WWU's SCITEC team. Thank you Carson Racicot and Erin Benson for your laboratory assistance. My appreciation goes to Todd Lagestee for his donation of experimental quartz crystal tools to the lab which greatly assisted in my post depositional surface modification analysis, along with his advice, photographs, and shared interest in quartz crystal microblades. I would like to thank Dr. Dale Croes for allowing me to use photographs from the Hoko River site. A huge thank you goes to Julia Rowland for her assistance, edits, advice, and constant support that kept me motivated and fueled my excitement for this topic. Finally, I would like to thank my family and friends for believing in me; your confidence and encouragement is something I will forever be grateful for.

Table of Contents

Abstract....iv

Acknowledgements....v

List of Figures....ix

List of Tables....xi

CHAPTER 1: INTRODUCTION.... 1

CHAPTER 2: QUARTZ CRYSTAL, MICROBLADES, AND QUARTZ CRYSTAL MICROBLADES.... 5

  Quartz Crystal Raw Material.... 5

  Global Use of Quartz Crystal.... 7

  Definition of a Microblade.... 8

  Production of Quartz Crystal Microblades.... 10

  Hafting Styles, Materials, and Microwear.... 17

CHAPTER 3: USE OF QUARTZ CRYSTAL DURING THE LOCARNO BEACH PHASE.... 22

  Microblades and the Locarno Beach Phase.... 22

  Quartz Crystal Microblades and the Locarno Beach Phase.... 24

    45CA426.... 24

    45CA213, The Hoko River Site.... 26

  Ceremonial Use of Quartz Crystal in the Gulf of Georgia Region.... 29

CHAPTER 4: METHODS.... 31

  Sample Selection.... 31

  Morphological Analysis.... 35

    Object Type.... 35

    Attribute Analysis.... 36

    Dimensions.... 38

  Microwear Analysis to Determine Location of Use and Haft Placement.... 39

History of Microwear Analysis 39
Previous Microwear Analysis on Quartz and Quartz Crystal 40
Goal of Microwear Analysis 41
Complete Blade Analysis Attribute and Location Definitions 44
Expectations of Microwear Patterns 48
Experimental Projects 51
Production Wear and Post-depositional Surface Experimentation 51
Residue Analysis 54
Energy-dispersive X-ray Spectrometry (SEM-EDX) 55
Cross-Over Immuno-electrophoresis (CIEP) Analysis 57
Botanical Analysis and Radiometric Dating 61
CHAPTER 5: RESULTS 65
Morphological Analysis 65
Comparison to Spear's (1977) Analysis of 45WH59 67
Dimensions 68
Presence of Cortex 72
Cross Section 74
Termination Type 76
Microwear Analysis of Complete Blades 77
Scar Orientation on Blade Edge 78
Scar Types Observed 79
Residue Analysis 83
Colors of Residues Observed 84
Compositional Analysis of Residues using Energy-Dispersive X-ray Spectroscopy 85
Cross-over Immuno-electrophoresis (CIEP) Protein Residue Analysis 90

Artifact Cleaning 94

Production Discussion 97

CHAPTER 6: DISCUSSION AND CONCLUSIONS 100

Morphological Analysis 100

Microwear Analysis 101

Residue Analysis 103

Conclusions 105

REFERENCES CITED 107

APPENDIX A: ATTRIBUTE ANALYSIS FORM 114

APPENDIX B: MICROWEAR ANALYSIS FORM 116

APPENDIX C: WALL PROFILES OF N1W1 AND N1W2 118

APPENDIX D: RESULTS OF BOTANICAL ANALYSIS 121

APPENDIX E: RESULTS OF RADIOMETRIC DATING 126

APPENDIX F: RAW ATTRIBUTE ANALYSIS DATA 132

APPENDIX G: MEASUREMENT DATA 136

APPENDIX H: COMPLETE BLADE ANALYSIS 140

APPENDIX I: SEM-EDX RESULTS 147

APPENDIX J: RESULTS OF CIEP ANALYSIS BY CSUBLAS 150

List of Figures

Figure 1. Orientation of a quartz crystal microblade. 9

Figure 2. Lithic Grade Scale ranking material types by ease of knapping 12

Figure 3. Side-hafted microliths from the Hoko River site 18

Figure 4. Photographs of an end-hafted quartz crystal microblade (Artifact #268) and side-hafted microlith of unidentified material (Artifact #215) from 45CA213. 19

Figure 5. Cedar microlith handle production from the Hoko River site 20

Figure 6. Select sites discussed in Chapter 3 with quartz crystal microblade assemblages. 24

Figure 7. Chart outlining methods of analysis on the sample assemblage. 32

Figure 8. Location of sites analyzed in the thesis, along with those previously discussed in Chapter 3. 34

Figure 9. Example of complete blade microwear analysis on Artifact #1591 from 45WH55 with differing wear patterns shown by color-coded dotted lines. 45

Figure 10. Examples of scalar, half-moon, and step scar types. 47

Figure 11. Example of scalar and step combination scar pattern. 47

Figure 12. Example of SC/SC scar pattern. 48

Figure 13. Post depositional surface modification along experimental tool edge. 54

Figure 14. Quartz crystal microblade collecting a charge while being exposed to the electron beam of a scanning electron microscope. 57

Figure 15. Mean lengths, widths, and thicknesses for artifacts in the sample assemblage 69

Figure 16. Horizontal striations characteristic of cortex 73

Figure 17. Artifact #407 from site 45SK46 with rounded distal tip and wear along left lateral edge. 76

Figure 18. Percentage of microwear on complete blades by blade edge portion. 77

Figure 19. Examples of differing microwear patterns along artifact edges. 80

Figure 21. Artifact #1591 from 45WH55 with a SCHM scar pattern covering its distal most portion. 82

Figure 20. Artifact #15 from 45WH59 with different microwear patterns covering almost the entirety of both lateral edges. 82

Figure 22. Examples of residues observed on microblade surfaces. 84

Figure 23. Colors of residues observed on artifact surfaces. 85

Figure 24. Artifacts with pigment residues and elevated iron levels from site 45WH59. 87

Figure 25. Platy texture of red ochre residue on Artifact #760 from site 45WH55. 88

Figure 26. Artifact #27 from site 45WH59, with residues including red ochre covering only the cortical surface. 89

Figure 27. Artifact #760 from 45WH55 with ochre covered distal tip. 90

Figure 29. Artifact #16 from 45WH59 before and after CIEP analysis. 96

Figure 28. Artifact #179 from 45WH01 before and after CIEP analysis. 96

Figure 30. Artifact #37 from 45WH59 with green crystal inclusions. 98

Figure 31. Flake with attached fiber on edge. 104

Figure 32. Attached particles to the distal end of a complete microblade. 105

List of Tables

Table 1. Dates, locations, and number of quartz crystal artifacts from sites included in the sample assemblage. 33

Table 2. Artifacts selected for CIEP analysis. 60

Table 3. Samples from 45WH59 chosen for radiometric dating. 61

Table 4. Artifacts from cut N1W1, 45WH59, associated with charcoal sample (Cat #64) 62

Table 5. Artifacts from cut N1W2, 45WH59, in association with charcoal sample (Cat #22) 63

Table 6. Total counts and percentages of artifacts in the sample assemblage. 65

Table 7. Total counts and percentages of types of microblades in the sample assemblage. 66

Table 8. Comparison of 45WH59 core measurements taken by Spear (1977) and this analysis. 68

Table 9. Comparison of 45WH59 microblade categories, Spear (1977) and this analysis. 68

Table 10. Core measurement comparisons between the sample assemblage and 45CA426 70

Table 11. Metric comparisons between microblades of the sample assemblage and those from 45CA426 71

Table 12. Microblade measurement (mm) comparisons between sites in the region. 72

Table 13. Presence (P) and absence (A) of cortex by artifact type and site. 73

Table 14. Microblade cross section shapes observed at each site. 74

Table 15. Cortex in Relation to Cross Section 75

Table 16. Termination types, counts, and percentages for the complete blades in the sample assemblage. 76

Table 17. Complete microblades exhibiting only a single type of scarring pattern on any/all edges. 79

Table 18. Types of scar patterns recorded on portions of complete microblades. 80

Table 19. Scar types within combination patterned portions. 81

Table 20. Antiserum types and possible species identified during CIEP analysis 91

Table 21. Results of CIEP analysis of samples of 25 quartz crystal artifacts sent to CSUBLAS. 92

CHAPTER 1: INTRODUCTION

It is well established that in the Salish Sea region of the Northwest Coast, quartz crystal microblades were manufactured and utilized almost exclusively during the dynamic cultural period of the Locarno Beach Phase (3500-2400 BP) (Ames and Maschner 1999; Carlson 1996; Matson and Coupland 1995; Mitchell 1990). Despite the diagnostic association and the widespread occurrence of quartz crystal artifacts in the region, there is very little research aimed at understanding the technological, economic, and social role that this industry played during this specific time period.

Specific functions of quartz crystal microblades during the Locarno Beach phase are suggested by researchers for two sites on the Olympic Peninsula of Washington State with exceptional recovery. Croes (1995) suggests association of hafted microblades and microliths of vein quartz with fish processing at the Hoko River site based on the faunal assemblage and residue analysis. Wet preservation at this site resulted in the recovery of an end-hafted quartz crystal microblade, and the opportunity to study hafting methods. At 45CA426, 571 quartz crystal artifacts representing various stages of production and use were recovered. They were associated with concentrations of elk bone and residue analysis indicated artiodactyl protein on 11 of the microblades (Walker 1999). Walker suggests that the use of quartz crystal to produce microblades was not simply an economic choice, but a cultural one.

Regional studies can draw on a great deal of previous research on microblades which shows commonalities between material choices and production strategies in industries from multiple regions spanning Asia and North America in different time periods. Microblade industries offer portability and flexibility. Microcores are small, light and can easily be transported between locations. Microblades, which are useful for a variety of purposes, can be produced expediently on location as needed.

Quartz crystal microblades co-occur with microblades of other materials in the Salish Sea and in other contexts, such as the Paleoarctic Tradition (Goebel and Buvit 2011). I suggest that they are a specialized subset of microblades because they offer functional advantages such as durability, and because quartz crystals commonly have cultural value in addition to its qualities as a toolstone. Unworked quartz crystals are associated with ritual and ceremony and ritual in many cultures, and there is evidence that both flaked and unflaked quartz crystal had significance to ancestral Coast Salish peoples (Hickok et al. 2010).

The paucity of research in this region specifically on quartz crystal microblades parallels a general lack of focus on quartz crystal as a raw material globally. Reher and Frison (1991) remark upon the fact that quartz crystal occurs ubiquitously but in always in low frequencies and is seldom given specific attention. The distinctiveness of raw quartz crystal as a material in regards to flintknapping techniques and lithic analysis is emphasized in the limited amount of experimental work that has been performed on both production and microwear (Flenniken 1981; Reher and Frison 1991; Igreja 2009; Lagestee 2012).

The goal of this thesis is to provide a better understanding of the function of quartz crystal microblades and the role they played for prehistoric peoples of the Salish Sea during the

Locarno Beach Phase. Previous research establishes specific uses for quartz crystal microblades that relate to specific locations: marine resources at the Hoko River site and elk at 45CA426. The fact that quartz crystal microblades are so widely found in small numbers throughout the Salish Sea region suggests that they share the general advantages of microblades in being portable and providing a flexible generalized use. I hypothesize that quartz crystal microblades were multi-use tools that were utilized for a variety of tasks. I further suggest that technological, functional, and social factors may all have played a role in why the technology was so common in the Locarno Beach phase but not at other times.

This thesis employs an innovative approach, applying a wide variety of technologies to an assemblage of 68 quartz crystal artifacts from six different sites in northwestern Washington State, 45SK46, 45WH01, 45WH17, 45WH47, 45WH55, and 45WH59. Morphological analysis separates artifacts into typological categories and describes their attributes in detail. Microwear analysis identifies use-wear patterns, the most commonly used edge, and possible prehistoric haft placements for individual tools. Residue analysis methods include the use of a scanning electron microscope equipped with an energy-dispersive x-ray spectrometer to identify inorganic residues, and cross-over immuno-electrophoresis (CIEP) protein analysis to identify organic residues. The combination of morphological, microwear, and residue analyses will provide not only a new perspective on the specific function of this tool, but also its place within the toolkit of peoples living thousands of years ago. The Locarno Beach Phase, and the artifacts associated with it are representative of a society in transformation and this alone justifies a closer look at the technological and social function of this specialized technology.

The following chapter provides an overview of microblades as a general technology, details about quartz crystal microblades, and a discussion of the global use of quartz crystals. Chapter Three discusses the Locarno Beach cultural phase and two sites located on the Olympic Peninsula that were especially beneficial to research on quartz crystal microblades. Chapters Four and Five provide details of the methods and results of morphological, microwear, and residue analyses. Chapter Six outlines the significance of this research for Northwest Coast prehistory and identifies opportunities for future studies of this lithic technology.

CHAPTER 2: QUARTZ CRYSTAL, MICROBLADES, AND QUARTZ CRYSTAL MICROBLADES

In order to better understand the manufacture and use of quartz crystal, one must first realize the special qualities of the material that create cultural symbolic value and affect its use as a toolstone. Production of microblades is a very distinctive technology, that while found in many times and places, is nonetheless relatively rare. Quartz crystal is equally distinctive as a raw material type, and while quartz crystals have been used widely, they are never common. This is reflected in the lack of research focused on the production and use of quartz crystal artifacts and technologies (Derndarsky and Ocklind 2001; Igreja 2009; Kimball 1994, 2013; Sussman 1985, 1988).

Quartz Crystal Raw Material

Quartz is a name used to refer to silicon dioxide (SiO_2), one of the most abundant and widespread rock-forming minerals on earth. It is a component of many metamorphic and igneous rocks, and can grow in crystal formations. This mineral usually develops in prisms that have 6 sides and are trigonal in shape (Anthony et al. 2001; Hamilton et al. 1978). Each crystal is a faceted cylinder with defined ridges between each of its crystal faces. Crystals vary in color and transparency depending on trace elements, and common names such as amethyst, citrine, milky, rose, and smoky quartz have been given to specific variants (Anthony et al. 2001; Hamilton et al. 1978). The clear crystal variety, commonly called rock crystal, is the only one regularly used for flintknapping. Quartz crystals grow in hydrothermal veins in geographic environments varying from alpine to epithermal and range in size from tiny prisms to crystals over 50 feet tall (Anthony et al. 2001). Single crystals can be found loose on the surface when they have been eroded from their formation environments, and may be transported by water. The natural cortex, or outer growth surface, on a quartz crystal face can be identified by characteristic horizontal striations on the stone's surface, perpendicular to the direction of growth (Hamilton et al. 1978).

Quartz crystal has an unusual fracturing behavior for a macrocrystalline material because it lacks cleavage planes. It does fracture conchoidally like the cryptocrystalline varieties of SiO_2 that are commonly flinknapped, such as chert and flint. Visible impurities, seen as rough areas or pockets on or within a quartz crystal are due to cavities being filled with liquid during crystal growth, or inclusions of other minerals within the stone. These impurities can interrupt a fracture, as can natural irregular internal planes that had developed at a slower or interrupted growth rate. These issues would be visible to flintknappers and could be avoided during tool production in order to remove a more complete flake or blade (Reher and Frison 1991).

Quartz crystal artifacts are seldom found as a dominant lithic material within site assemblages, but are recorded in small numbers in sites throughout the world (Reher and Frison 1991). Sussman suggests that despite its ubiquity, quartz crystal as a material type has been overlooked in analyses due to its "irregular fracture pattern and surface texture, high reflectivity and hardness" (1985:101). These qualities make analysis of artifacts made of this material physically challenging, while the differences between quartz crystal and other lithic material types limit direct comparison.

Comparative research is hampered by inconsistency in terminology and a failure to distinguish between different varieties of quartz. Often, the general term “quartz” is used without an explicit indication as to which variety was present in assemblage. Cryptoscrystalline quartz (CCS), vein quartz, and quartz crystals, should not be lumped together simply as “quartz” because these materials are not comparable in production, fracturing, or wear patterns. Prehistorically, vein quartz was commonly utilized for lithic tool manufacture across the globe. Although it contains the same mineral combination, vein quartz is formed in veins of rocks. More resistant than the parent rock, it weathers out and may undergo water transportation to become a useable form to flintknappers, such as pebbles (Andrefsky 2005; Driscoll 2009 and 2010; Flenniken 1981). Quartz crystal artifacts deserve treatment as a category of their own, as I would not connect the similarities in microwear patterns between “quartz” and quartz crystal any more closely than I would compare those materials with obsidian.

Global Use of Quartz Crystal

Association of quartz crystal and quartz crystal tools with shamans and ceremonial activities is noted extensively in ethnographic literature. Various groups around the world associate quartz crystal with religious, spiritual, and healing behaviors (DuBois 2009; Eliade 1972; Kalweit 1992; Knutsson 1988; Trueblood et al. 1977). The prismatic shape and distinct clarity of quartz crystal causes it to stand out among other flakeable lithic materials.

Additionally, it produces a piezoelectric charge when it is struck, a phenomenon known as triboluminescence (Hickok et al. 2010). This reaction impressively causes a dazzling flash of light and occasionally a bright spark. The locations in which quartz crystals are found, such as caves and mountain ranges, could also be associated with shamanistic travel such a spirit quests.

Whole unmodified quartz crystals are considered to be the most important element of the magical toolkit used by healers in North Borneo and Celebes (Eliade 1972). The Cobeno of South America use the stones as symbols of strength and healing and see crystals as gifts from celestial spirits known as Cenoi. Cenoi also often reside within the individual crystals. The use of quartz crystals by prehistoric peoples of the Northwest Coast region of North America is discussed in Chapter 3.

Definition of a Microblade

Microblades are small, uniform, sharp cutting tools that are systematically removed from a prepared core by applying a semi-vertical force to the edge of the platform to remove an elongated flake (Andrefsky 2005; Odell 2004; Smith 1997). Microblades are distinguished from standard blades by their small size. They measure only centimeters in length, are typically at least twice as long as they are wide, and exhibiting parallel lateral margins (Andrefsky 2005:165; Desrosiers and Gendron 2004; Kuzmin et al. 2007; Mason and Perino 1961; Smith 1997). Their longitudinal axes vary minimally in width and thickness and can be oriented by identifying their platform (proximal) and termination (distal) ends (Figure 1). The dorsal surface of a microblade exhibits arises from previous flakes or blades and occasionally the natural cortex of the raw material. The ventral surface of a microblade often contains a slight bulb at the point of impact, with ripples and fissures moving away from the proximal and towards the distal end of the blade.

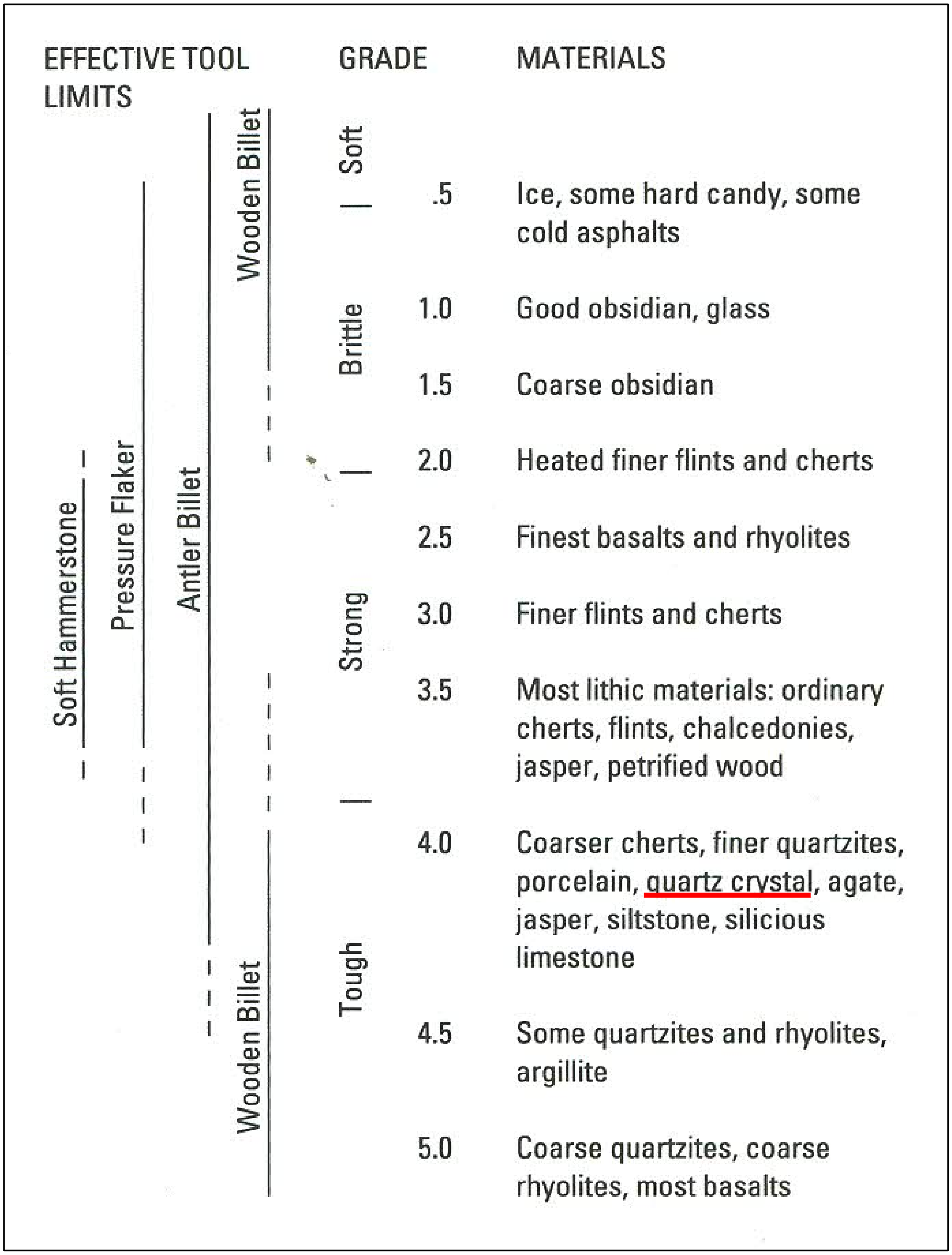
Figure 1. Orientation of a quartz crystal microblade (dorsal view).

Microblades, and similar core reduction technologies, are found in prehistoric assemblages in northwestern areas of North America, most notably in Alaska during the Paleo-Arctic (8000-5000 BC) (Fagan 1991). Ethnographic literature specific to the functionality of microblades is rare, so much of our knowledge of the general function of this tool type is from lithic analysis. Lithic analysts have studied microblade industries from contexts all around the world (Andrefsky 2005; Odell 2004). The variability of geographic and environmental locations in which these prehistoric tools have been recorded support the overall flexibility and utility of this technology. Andrefsky (2005) suggests that microblades were used during multiple activities and varied in function based on tool size and the context in which a microblades was needed. Microblades may have been utilized for a multitude of behaviors ranging from precision craft work to basic utilitarian activities. This includes bead making (Mason and Perino 1961), drilling, engraving bones, hair cutting, shaving, and cordage or basketry making (Hutchings 1996). They would have also been extremely useful and efficient in plant, hide and meat processing tasks (Hutchings 1996; Walker 1999).

Production of Quartz Crystal Microblades

Quartz crystals make good cores because of their natural prismatic and cylindrical shape, much like the prepared cores of other microcore technologies (Reher and Frison 1991). As suggested by experimental quartz crystal production projects, most of the required preparation for the removal of microblades would be performed by grinding on the striking surface, or platform, of a core. This preparation is needed in order to apply a blow, likely above a ridge formed by the intersection of natural crystal faces, to remove a microblade (Flenniken 1981; Igreja 2009; Lagestee 2012; Reher and Frison 1991). The use of microcore reduction strategies on quartz crystals conserves the resource, which is important because only a small amount of material is available in each core. Little preparation is necessary to remove microblades. These microblades have the standard features, including a striking platform, bulb of percussion, fissures, and termination.

In comparison to other lithic materials used to make stone tools, quartz crystal may have required greater skill or a larger production toolkit due to the stone's hardness and fracturing patterns. Like chert and other CCS materials, quartz crystal ranks 7 on Moh's Scale of Hardness, while obsidian ranks at 5. The harder the material, the greater the pressure and applied force is needed to gain the desired result and control the lithic fracture. Whittaker (1994) ranks materials by ease of flintknapping on his Lithic Grade Scale (Figure 2). Quartz crystal is included in the "tough" grade and measures at 4.0 out of 5.0 with agate and jasper, while other commonly used chipped stone raw materials such as chert and obsidian fall into the "strong" and "brittle" grade categories and measure at between 1 and 3.5.



GRADE	MATERIALS
.5	Ice, some hard candy, some cold asphalts
1.0	Good obsidian, glass
1.5	Coarse obsidian
2.0	Heated finer flints and cherts
2.5	Finest basalts and rhyolites
3.0	Finer flints and cherts
3.5	Most lithic materials: ordinary cherts, flints, chalcedonies, jasper, petrified wood
4.0	Coarser cherts, finer quartzites, porcelain, quartz crystal, agate, jasper, siltstone, silicious limestone
4.5	Some quartzites and rhyolites, argillite
5.0	Coarse quartzites, coarse rhyolites, most basalts

Figure 2. Lithic Grade Scale ranking material types by ease of knapping (from Whittaker 1994:66).

Reher and Frison (1991) utilized segments of large Brazilian crystals in experimental research. They state that the reduction of quartz crystal is similar to that of chert, but that the former material lacks some of the flexibility of the latter. During reduction, the incorrect application or angle of force can cause a flintknapper working a piece of chert to obtain a less than ideal flake that does not exhibit the desired features, length, or thickness. The same action when working quartz crystal can cause an unpredictably shaped and rough flake. Worse yet, a poorly executed strike can cause a crystal to shatter upon impact, exhausting the core for any additional blade removals. Reher and Frison (1991:379) state that the removal of blades from a quartz crystal:

> …require[s] a more robust platform and a point of impact further back from the platform edge due to its more brittle nature. Along with this, however, less force is required for fracture propagation once the fracture is initiated. It is difficult to put into words, but it seems almost as if a slightly sharper blow or applied pressure is required for fracture initiation, and then results are more favorable if the knapper almost instantaneously "backs off."

Reher and Frison describe other flintknappers' reactions to crystal knapping as "limited success if not outright failure" (1991:378). The level of skill required to produce tools out of quartz crystals would have been advanced. The authors emphasize the difficulties and frustrations of the material type stating: "crystal knapping is a study in contradiction, since one flake can come off as though from the finest obsidian while the next suddenly turns into so much crystal dust in a knapper's hand" (Reher and Frison 1991:393).

Reher and Frison (1991) list their lithic toolkit for the reduction of quartz crystals as hammerstones, pressure flakers, and antler batons. During experimentation on quartz crystals of various sizes and qualities, they successfully removed some blades with a hammerstone, needing only a limited amount of grinding to prepare a flat and even platform between blows. The rigid quartz crystal material allows for a sturdy platform, but the fragility of its inner structure discourages knappers from applying any unnecessary blows during preparation for reduction.

It would seem natural to use either the attachment or terminal end of the crystal as a striking platform. The attached end from which new crystal growth occurred would only need to be flattened to become a suitable platform, while the terminal end of the crystal would need to be removed and then flattened. The authors reference communication with other flintknappers, who suggested that a crystal could only be reduced unidirectionally. Reher and Frison (1991) disagree; and chose to not be guided by the natural crystal faces in some of their experimentation, and still successfully removed usable blades and flakes. The authors suggest that any part of the crystal could be prepared as a regular striking surface, including facets and other platforms prepared during production. They found that during their flintknapping, the rate of failure increased when removing flakes from multiple directions on a crystal, but that it was not impossible to remove blades multi-directionally. The authors noted that blades that broke during production were still able to be utilized, and had desirable traits for processing behaviors, such as scraping.

Despite Reher and Frison's (1991) success when using a hammerstone on larger crystals, it is probable that tools other than just a hammerstone would be needed to apply sufficient localized force to the platform of a core in order to remove a microblade. The toolkit used for the production of quartz crystal microblades using indirect percussion may have included a variety of wedge and punch implements, such as hammerstone and tines. Flenniken (1981) suggests a vise and pressure flaking technique may have been utilized in the production methods of quartz crystal microblades. Experimental work by Lagestee (2012) successfully produced quartz crystal microblades using a vise and an indirect percussion technique. His project utilized modern tools such as a grinding wheel, metal vise, and metal pins. Lagestee suggested that the difficulty in production methods he experienced in comparison to that of Reher and Frison (1991) report was due to the difference in core size, as he was using small crystals from Washington State while Reher and Frison reduced pieces of large Brazilian crystals (Lagestee 2012).

Although quartz crystal is difficult to knap, the effort is rewarded by tools that are stronger and more durable than those made from other chipped stone materials. Quartz crystal microblades are sharp and precise, and when comparing them to other lithic tools, would have remained so for a longer duration without retouch than tools of other materials. Igreja (2009:9) discusses this positive utility during experimentation stating:

> …quartz is especially accurate to butchering, as the cutting capacity of the edge remains the same in spite of time using. The side hafted rock crystal bladelets were particularly effective and much longer, no matter the hardness of the contact materials (meat, hide and tendons).

Due to their small size, quartz crystal microblades are highly portable, but their fragility would need to be taken into account during transportation. As an alternative, microblade cores which are also relatively small and light, could be easily transported. It is likely that microblade tools were prepared in an expedient manner on location for immediate use (Greaves 1991; Walker 1999).

Walker compiled a list of 16 sites with microblade assemblages located in the Salish Sea region; quartz crystal is noted as a material in 13 components that date to or include the Locarno Beach Phase, and 4 Marpole Phase components (1999:Table 14.5). The low frequency of quartz crystal microblades in cultural phases other than the Locarno Beach and Marpole phases is suggested as a cultural preference influenced by access to raw materials, or new technological strategies (Walker 1999).

At site 45CA426, on the Olympic Peninsula of Washington State, quartz crystal was deliberately chosen over other lithic raw materials that were available close to the site. This choice was described as one that was culturally, rather than economically, motivated as the quartz crystal raw material was not immediately available, the production technique was labor intensive and specialized, and that other tools and material types, such as dacite and fine grained basalt, were more readily available could have provided the same function (Walker 1999). Even though quartz crystal microblades were likely more difficult to manufacture and were made of a less abundant material type, they still dominated the chipped stone assemblage at 45CA426.

Hutchings (1996) suggests both raw material access and technological organization as factors in changing use and production of microblades at the Namu site in British Columbia.

The relatively sudden disappearance of the obsidian microblade industry after 4500 BP is likely linked to a decline in obsidian access between 4500 and 3500 BP. When obsidian reappears after 3500 BP, it was used to produce microliths rather than microblades, indicating a shift in technological organization.

Hafting Styles, Materials, and Microwear

Like other small lithic tools, microblades are generally assumed to have been used in hafts. Hafting would increase the leverage and pressure that could be applied to the tool while reducing the risk of injury to the handler (Croes 1995). Microblade hafting methods involve attaching the tool to a handle, generally by inserting it into a slot in a shaft, and then adding some sort of adhesive and wrapping to keep the microblade in place (Croes 1995; Helwig et al. 2008). Opportunities to directly observe and analyze prehistoric hafting methods and materials are limited, as hafts are most commonly organic, and break down quickly in most depositional environments. Two sites in northwestern North America with environmental conditions that allowed for the preservation of hafting materials are the Hoko River wet-site of the Olympic Peninsula of Washington State (Croes 1995) and the Gladstone Ice-patch site of Southwestern Yukon, Canada (Helwig et al. 2008).

Helwig et al. (2008) describes the analysis of preserved materials at the Gladstone Ice Patch, a site labeled as a hunting and animal processing area dating to 7310 ± 40 BP. These materials include wood, stone, antler, sinew, rawhide, and feathers. Hafting adhesives and “red paint" were recorded on a double slotted antler point used to mount microblades. The use of Fourier transform infrared spectroscopy (FTIS) and gas chromatography-mass spectrometry identified the adhesive as conifer resin. The authors suggest the resin was spruce, and was unlikely to have been heated. No suggestion was made on whether wrapping would have been used in conjunction with the adhesive to secure the microblade. The use of microblades in composite tools made of bone and antler has also been noted at many sites throughout Siberia and Alaska (Ackerman 1996).

Some quartz crystal microblades and vein quartz microliths recovered at the Hoko River site were found with organic hafting material still attached. Hafting materials found preserved at the Hoko River site were made of split western red cedar and cedar bark with binding materials split spruce-root and cherry bark with no indication of the use of an adhesive (Croes 1995:180) (Figure 3).

Figure 3. Side-hafted microliths from the Hoko River site, complete with hafting material. Photograph courtesy of Dale Croes.

The individualized hafting of each microblade allows for a range of edges and lengths to be exposed, depending on the task required. The Hoko River site exemplifies two general types of prehistoric hafting methods: end-hafting and side-hafting (Figure 4). End-hafting is the attachment of the microblade to the distal end of a haft. To do this, the proximal end of the microblade is inserted into the shaft, exposing the sharp distal end of the tool and both lateral blade margins for a total of three cutting edges. Side-hafting involves the parallel attachment of a lateral edge of a microblade(s) to the side of a wooden handle to form a tool most similar to a present-day knife.

Figure 4. Photographs of an end-hafted quartz crystal microblade (Artifact #268) and side-hafted microlith of unidentified material (Artifact #215) from 45CA213, The Hoko River Site. Photo courtesy of Dale Croes.

Flenniken describes the raw material for the hafts as coming from three sources: wood split from living trees, driftwood, or cedar scrap wood already present at the site (1981:61). The stages of handle manufacture are outlined in (Figure 5). He describes haft preparation as needing:

> … considerable preparation prior to use. After the materials were collected or gathered from the forest, they were cleaned and stripped of the non-functional parts and then soaked in water to make them more pliable. Once pliable, they were spilt by various methods into the desired length, width, and thickness for binding elements [Flenniken 1981:71].

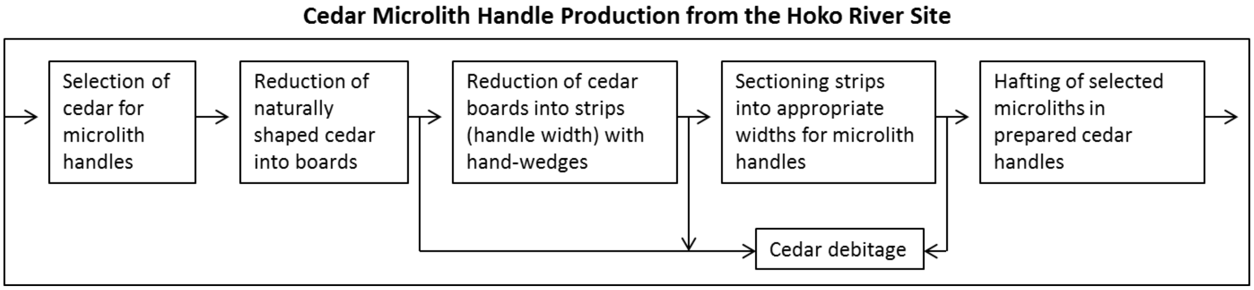


Figure 5. Cedar microlith handle production from the Hoko River site (Flenniken 1981:61, Figure 36).

Multiple methods for the side-hafting of quartz microliths were observed at the Hoko River site and replicated in experimental projects by Flenniken (1981). The first was vise-like, with a microlith being placed between two separate strips cedar that were then wrapped. The second involved the insertion of the tool in a single piece of cedar that was split a small distance across the wide axis of the strip. The third was not a full split, but rather a small slot in which the microlith was placed. For binding, he employed spruce root (*Picea sitchensis*) and cedar bark (*Thuja plicata*), both observed on the prehistoric artifacts and available locally.

In the absence of preserved hafting materials, archaeologists may use microwear and residues to reconstruct hafting. Mason et al. (1961) analyzed flint microblades from the Cahokia site in the American Bottom, Illinois. Microblades associated with the Mississippian cultural period are thought to have been used as tools in the bead production process (Mason et al. 1961). The authors suggest that these tools were end-hafted, as indicated by traces of resin and pitch on their surfaces, and by scarring patterns on blade edges. This determination of function was based on the presence of rotary wear and polish viewed during microscopic analysis.

CHAPTER 3: USE OF QUARTZ CRYSTAL DURING THE LOCARNO BEACH PHASE

Quartz crystal microblade artifacts are most commonly associated with the Locarno Beach Phase, an important cultural transition period in the Salish Sea region of the Northwest Coast of North America. In this chapter, previous research on this specific tool technology and sites with quartz crystal artifact assemblages are discussed.

Microblades and the Locarno Beach Phase

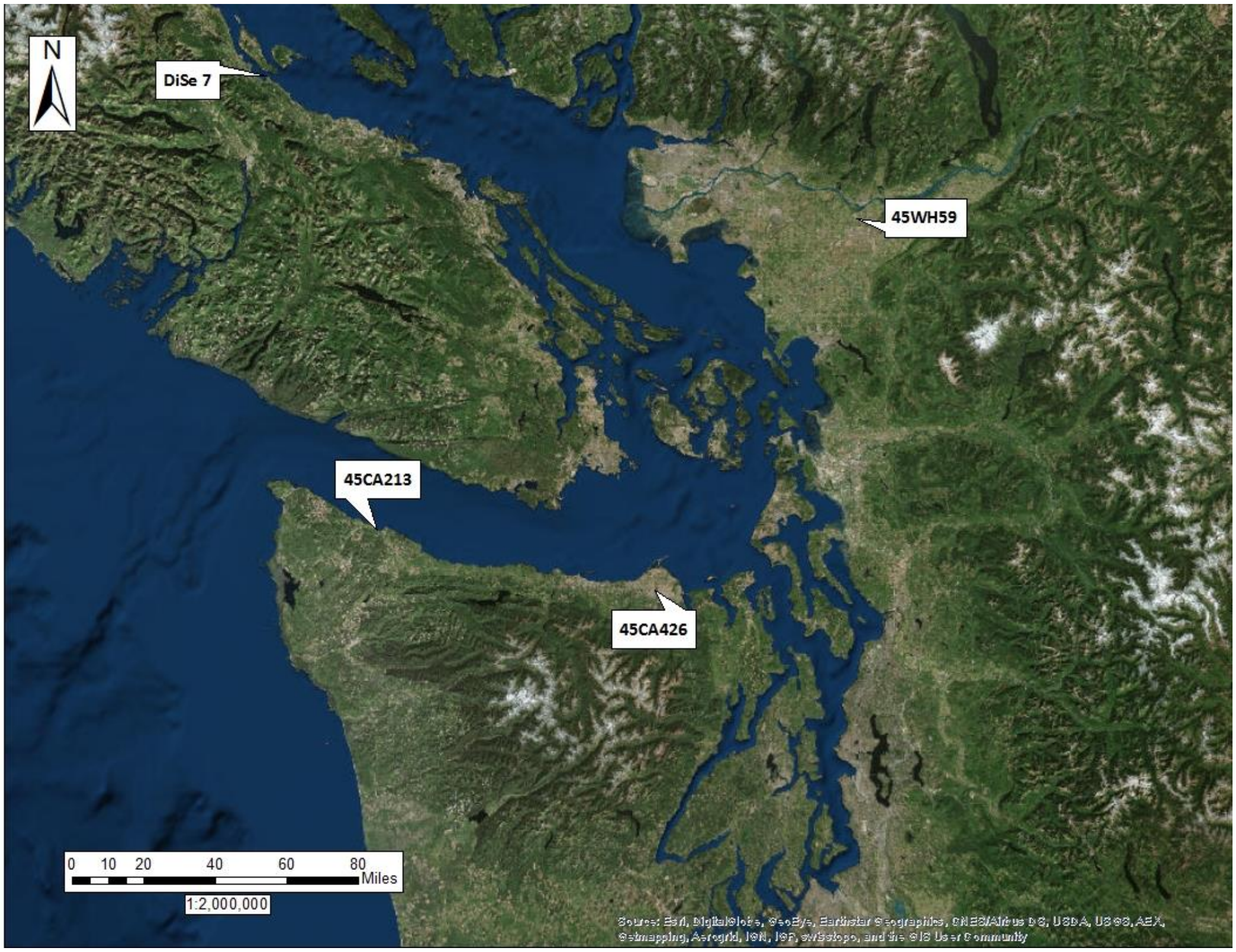
The Locarno Beach Phase (3500-2400 BP) is a cultural phase defined for the Gulf of Georgia, a subregion of the Northwest Coast culture area which included the Salish Sea (Matson and Coupland 1995:154). A number of stylistic markers distinguish the Locarno Beach Phase from the preceding Initial Coast Adaptation Phase (4500-3000 BP), and the following Marpole Phase (2500-1400 BP). Sites and associated artifacts from the Initial Coast Adaptation Phase suggest no intensified use of resources and a lack of social ranking (Ames and Maschner 1999; Carlson 1996; Matson and Coupland 1995; Mitchell 1990). In comparison, the Marpole Phase shows evidence of intensification of resources, large seasonal settlements, use of luxury goods, craft specialization, widespread ceremonies, and leaders participating in a hierarchical social structure (Ames and Maschner 1999; Mitchell 1990; Carlson 1996). The presence of a hierarchical social structure during the Locarno Beach Phase is suggested by grave goods, labrets, and ear spools, which Carlson (1996) links to members of higher social rank. In general, the Locarno Beach Phase marks the transition of group structure from mobile foragers to complex foragers.

Greaves (1991) analyzed lithic assemblages from sites on British Columbia's southern interior plateau. The author discusses the manufacture, stages of use, function, and preference of tool types on a sample of microcore tools from Upper Hat Creek Valley and Highland Valley. The goal of the Greaves's research was to determine the overall role of these tools. She concludes that microcore tools were highly transportable and widely distributed multiuse tools that would have benefitted both primary collectors and primary foragers.

A functional analysis was performed by Hicks (1991) on a sample of microblade artifacts made of a variety of materials. His assemblage was compiled from 19 sites in the Northwest Coast region dating between 6000-300 BP. Hicks analyzed assemblage and site variability and concluded that microblades were associated with sites of varying function, indicating that microblades were most likely a generalized technology.

Hicks (1991) suggests that microblades would be more commonly deposited in sites interpreted as field camps rather than residence bases, based on the assumption that the tools would be transported in the core state (Hicks 1991:61). The occurrence of microblades at 45CA426 does not follow this pattern as the majority of the tools were found within one housepit feature (Walker 1999). Similarly, the majority of quartz crystal artifacts at 45WH55 were found within a pit-house feature (Lewis 2013:125).

As part of his analysis, Hicks (1991) examined use-wear on microblades from 45WH59 (Figure 6), a site also analyzed in this thesis. Wear was observed on 25 of the 26 of the quartz microblades (96%), and one of the two basalt microblades. No wear was observed on the single chert microblades. This high percentage of wear may indicate that quartz crystal microblades were more intensively used and re-used in comparison to other materials. This may be due to the desired material type attributes, such as strength and durability.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6. Select sites discussed in Chapter 3 with quartz crystal microblade assemblages.

A large lithic assemblage including 571 quartz crystal artifacts was recovered from 45CA426, a site located on the northern Olympic Peninsula (Walker 1999). This site is unusual because quartz crystal makes up 60 percent of the site's chipped stone assemblage. Generally, at archaeological sites within the Northwest Coast region, quartz crystal is represented in only small quantities in comparison to other lithic materials. Microblades at 45CA426 are exclusively made of quartz crystal, and artifacts were separated into the following object types: microblades, cores, core fragments, modified flakes, unmodified-flakes, chisels/wedges, gravers, and debitage. A single biface was also recorded at the site (Walker 1999). The majority of these artifacts were recorded in association with elk metapodials within one semi-subterranean housepit feature. The housepit was dated to 2250 ± 60 and 2,480 ± 50 BP using 2 hearth feature samples. Other quartz crystal artifacts were recorded outside of the housepit feature in a meat processing area.

Walker (1999) compares metric data between the microblades at site 45CA426 to 5 other selected sites in the region (45CA213, DcRt10, DcRt13, DfRu24, DhSe2), and notes little variation between mean tool measurements of length, width, and thickness. Crushing on the base of a quartz crystal core from site 45CA426 suggests that a vise or anvil rest may have been used during microblade production (Walker 1999). Cores from the site have flake scars suggesting platform preparation, along with overlapping unidirectional scars from blade removal. Examination of the blades for use-wear showed that wear was more common at the distal rather than the proximal end of the tools which suggests the artifacts were end-hafted rather than side-hafted (Walker 1999).

Walker (1999) also discusses the transportation and production of quartz crystal microblades. She assumes that raw quartz crystal material and prepared cores could be easily transported, and that the actual production of these microblades would have most likely occurred close to the time and place of use as argued by Greaves (1991). Because quartz crystal microblades themselves are more fragile than the original crystals/cores, this choice would assure the tool was not subject to any unnecessary wear or potential crushing.

Walker (1999) used the enzyme linked immunosorbent assay (ELISA) method for the analysis of residues on a sample of quartz crystal tools from the 45CA426. This technique is broken into two categories: broad and narrow. The results from the tests on 20 tools produced 3 strong and 8 weaker broad positives from the order Artiodactyl. Possible sources include white tail deer, mule deer, elk, moose, antelope, or bison. One artifact that reacted with a strong broad positive underwent narrow testing which resulted in a positive test for moose/elk. Overall, both the broad and narrow results of this analysis are consistent with the large presence of deer and elk remains at the site, and more specifically, the deposition of quartz crystal microblades with elk metapodials on the house floor adjacent to a hearth feature (Walker 1999:14.15).

45CA213, The Hoko River Site

The Hoko River wet site (45CA213), located on the northern coast of the Olympic Peninsula, is interpreted by Croes (1995) to be a fishing camp dating to between 3000 and 2500 BP. In this wet portion of the site, artifacts including tools made of quartz crystal, vein quartz, and chert, were excavated with hafting components still attached. This discovery provides evidence of the orientation and placement of lithic tools within hafts in use during the Locarno

Beach Phase. Hafting materials were also identified, including the materials utilized for handles, resins, and wraps (Croes 1995; Croes and Blinman 1980).

Flenniken (1981) describes the production of both microliths and hafts at the Hoko River site. Microliths are small stone tools that are not true blades, but have similar dimensions, hafting methods, and general potential functions as microblades. The author defines microliths as "small specialized flakes that are quite short (average of 10.5 mm in length) and have at least one margin not necessarily a lateral margin, that is sharp" (1981:46). They were produced from vein quartz pebbles/small cobbles using bipolar reduction. Flenniken (1981) suggests that the presence of both quartz microliths and quartz crystal microblades represents the use of locally available resources as well as transported materials from other seasonally used locations.

Quartz pebbles are easily accessible from a large quarry spot on a spit beach less than 500 m from the Hoko River site. On the basis of replication experiments, Flenniken (1981) suggests that microlith tools could be rapidly produced and discarded at the site. This is supported by the over 40,000 of pieces of vein quartz microlith debitage discovered at the site (Croes 1995). In contrast, the quartz crystals needed to make microblades would not have been locally available. Quartz crystal artifacts were far less frequent than at 45CA426, consisting of only 23 microblades and a single potential core. The rarity of this technology suggests that these artifacts were produced at another location and transported to the site (Flenniken 1981).

A single end-hafted quartz crystal microblade was hafted using the same materials as the side-hafted microliths found at 45CA213. These hafting methods could have been easily used interchangeably between the two lithic material/tool types both at this site and at other sites in the Northwest Coast Region. The similarities in hafting methods and materials between vein quartz microliths and quartz crystal microblades at the Hoko River site suggest that though lithic sources and production differed during seasonal settlement, hafting methods likely stayed the same (Croes 1995).

Croes (1995) and Flenniken (1981) sought input from members of the Makah Tribe to infer microlith and microblade function. Based on experimentation, the authors had concluded that side-hafted vein quartz microliths were not suitable tools for cordage or basketry making. Three Makah basket weavers commented that they did not have a similar tool in their basket making toolkits. Another activity that the side-hafted vein quartz microliths lacked utility for during experimentation was the carving of wooden materials. A Makah wood carver gave his opinion that he did not believe it would have been a useful element of a prehistoric woodworking toolkit (Flenniken 1981). Croes (1995) also notes the suggestion by a senior citizen of Neah Bay that the end-hafted quartz crystal microblade may have been used for minor surgeries such as lancing boils.

Croes (1995) discusses a residue analysis performed by Tom Loy on isolated tools (not preserved in hafting material) from the Hoko River site. Loy identified red blood cells belonging to fish on 8 of the 13 quartz crystal microblade edges, one of which additionally exhibited the presence of bark. These residues were described as being "generally found near the lateral edges and most often in or near microflake scars along the extreme edges" (Croes 1995:186).

Ceremonial Use of Quartz Crystal in the Gulf of Georgia Region

Ethnographic accounts from the Gulf of Georgia region indicate that quartz crystals held symbolic significance for ancestral Coast Salish peoples who associate the stone with shamanistic powers of weather control, flying, healing, divination, and clairvoyance (Hickok et al. 2010). Archaeological evidence supporting the connection between quartz crystals and ritualistic activities is limited, but suggests a deep antiquity for the symbolic significance.

The burial of a woman believed to be a shaman at the S'oksun site (DiSe 7) at Deep Bay on Vancouver Island provides the strongest connection between quartz crystal artifacts and a ceremonial context. Individual 1 was a female with cranial manipulation who died of natural causes. The placement of her body suggests the uniqueness of the burial as she is the only interment found with hands placed over eyes. She was covered in an unusually large amount of red ochre, a material used in Coast Salish ritual practices for the enhancement of, or protection from, spirit-power. In addition to the red ochre, Individual 1 was evenly covered with 35 pieces of shattered stone (21 pieces of quartz crystal and 14 of obsidian). A quartz crystal microblade and two obsidian microblades were also recorded with the remains. The burial is not directly dated, but likely falls between 2500 and 1600 B.P. Deposits below the burials returned dates of 5220 ±80 BP and 4640 ±60 BP, however, her Cowichan style cranial modification is thought to date no earlier than 2500 BP. Stylistically, the grave goods could fall anywhere within the

Locarno Beach and Marpole phases between 3300-1600 BP. Four quartz crystal flakes were recorded in another burial at the site. Less is known about this internment, Individual 3, due to disturbance (Hickok et al. 2010). Hickok et al. (2010) suggest that based on ethnographic accounts, the quartz crystal fragments within both burials may have served the purpose of protecting the individual, or to limit them from using their powers beyond the grave.

Curtin (1999) reports a quartz crystal microblade found in a burial pit feature at the Tsawwassen shell midden site (DgRs 2). DgRs 2 is a large site on the Fraser River delta, south of Vancouver, B.C., which has deposits ranging between 4260-210 BP. The microblade was recorded within the skull of the adult male of Burial D-20, an internment that could not be assigned to a particular component. The author did not discuss the unique placement of the artifact within the skull and categorized the microblade as a utilitarian item that did not likely indicate wealth or social standing.

CHAPTER 4: METHODS

The goal of this analysis is to better understand the prehistoric function of quartz crystal microblades as multiuse tools in the Salish Sea region. It is achieved by a multipart analysis on a sample of quartz crystal artifacts from six sites in northwestern Washington State. In this chapter, I discuss the three major methods utilized in this research: morphological, microwear, and residue analyses. The combination of these analytical methods allowed for a large variety of data to be collected and analyzed for each artifact of the assemblage. This collection can provide insight as to the individual tool use, along with patterns in tool type and assemblage attributes. Figure 7 outlines the multiple methods utilized in the analysis of this quartz crystal artifact assemblage.

Sample Selection

Previous authors and analyses identified several sites in Western Washington University's repository whose assemblages included quartz crystal artifacts: 45WH59 (Spear 1977; Hicks 1991); 45WH55 (Lewis 2013); and 45SK46 (Mather 2009). By reviewing site catalogues, I identified three additional sites, 45WH1, 45WH17, and 45WH47 with quartz crystal artifacts (Table 1, Figure 8).

Artifacts
45SK46= 12
45WH1= 4
45WH17= 1
45WH47= 1
45WH55= 9
45WH59= 41

Method	**Morphological**	**Microwear**	**Residue**
Handlens (1-20X)	N= 68 Object type identification, Attribute Analysis Form	N= 68	N= 68 Identified visible residues, color identification
Stereomicroscope/ Dissecting Microscope (1-100X)	N= 68 Photographed at multiple scales	N= 28 Complete blade microwear analysis	N= 68 Verification of visible Residues/color identification
Scanning Electron Microscope (SEM) with Energy-Dispersive X-Ray Spectrometer (SEM-EDX) (1,000-150,000X)	N= 29 Examined and photographed		
CIEP			First sample set– N=15 Second sample set– N=10 Total– N=25

Figure 7. Chart outlining methods of analysis on the sample assemblage.

Table 1. Dates, locations, and number of quartz crystal artifacts from sites included in the sample assemblage.

Site Number	Location	Environment	Age (BP)	# of Quartz Crystal Artifacts	Screen Size used during Excavation	Reference
45SK46	SW Fidalgo Island, Deception Pass	Rocky headland on a marine channel	3500-2400	12	1/8"	Mather 2009
45WH1	SE of Cherry Point, Whatcom County	Mainland on open coast	3340-960	4	1/4"	Rorabaugh 2009
45WH17	Semiahmoo Spit, Whatcom County	Base of spit between bay and open coast	4715-350	1	1/4"	Montgomery 1979
45WH47	Padden Creek, Bellingham	Small creek going into a bay	2330-1960	1	1/4"	Beta Analytic Inc. 2011
45WH55	Northern Chuckanut Bay	Headland above small bay	2750-2450	9	1/8"	Campbell et al. 2010
45WH59	Bertrand Creek, Lynden	Terrace on Nooksack River floodplain,~20 miles from delta front	5500-3000	41	1/4"	Spear 1977

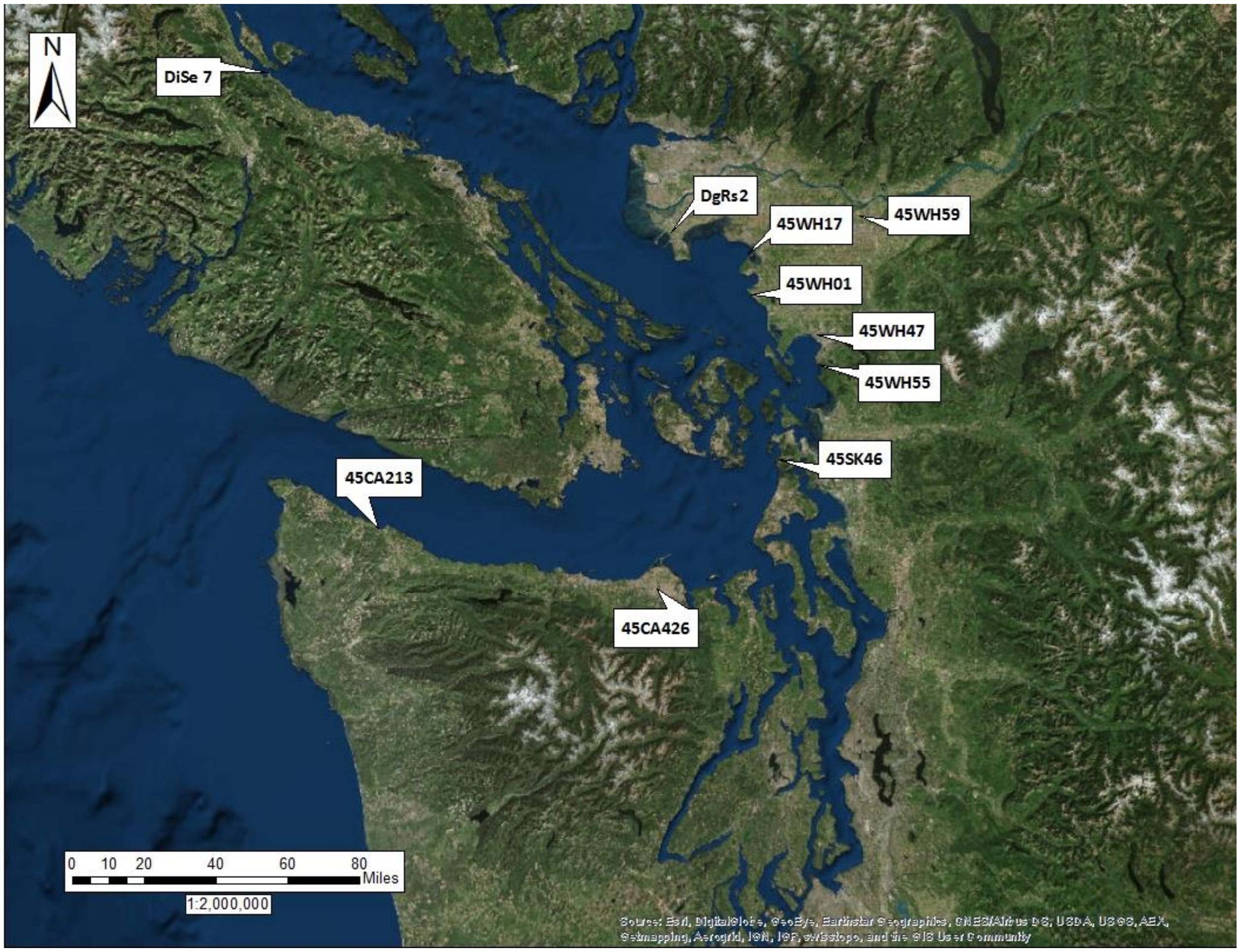


Figure 8. Location of sites analyzed in the thesis, along with those previously discussed in Chapter 3.

I collected previously identified artifacts and reviewed site catalogues and lithic collections to compile a quartz crystal artifact assemblage, referred to as the sample assemblage. All previously identified and catalogued quartz crystal artifacts in WWU's collections were located. Site lithic catalogues and assemblages were then further reviewed for potentially missed or misidentified artifacts. This required visual checking of all artifacts labeled "quartz" or "microblades" in artifact catalogs. When all potential quartz crystal artifacts from across the collections were compiled, further analysis was conducted to assess whether the material type had been properly identified. Some misidentifications included historic glass and lithic tools of a different material type, such as agate or vein quartz.

Many of the quartz crystal artifacts were originally housed in plastic bags or vials filled with tissue paper. They were repackaged in individual plastic bags within a larger plastic bag backed with supportive foam. This minimized any additional wear from handling or curation. To eliminate the transmission of modern residues by myself and others, no artifacts in the assemblage were handled without wearing gloves.

Morphological Analysis

The goal of the morphological analysis was to identify variation in artifact types and attributes present in the assemblage. These attributes, especially size, cross section shape, termination style, and the presence of cortex, allowed for comparative analysis within the assemblage and against other assemblages.

Object Type

In order to determine the morphological and potential production stages present in the assemblage, I used the following mutually exclusive object types to categorize each artifact: core, microblade, flake, and shatter. Following Andrefsky (2005), Banning (2000) and Hicks (1991), I defined categories as follows.

Core: a piece of quartz crystal that has been utilized to produce microblades. Most cores exhibit multiple flake scars from the removal of microblades. Cores may be exhausted (unable to produce blades) or active (have potential for blade production), and often have cortex covering a large portions of their surfaces.

Microblade: a small, thin, linear flake that exhibits parallel lateral margins that displays flake elements including arrises, fissures, and ripple marks moving away from the point of impact towards the distal end. An arris is a ridge formed between flakes scars on the dorsal surface of a flake. Natural ridges at the meeting of crystal faces are also are found on the dorsal surfaces of tools in this assemblage. Fissures and ripples are both found on the ventral surface of a tool and radiate away from the point of percussion. Fissures are small fracture lines; ripple marks are wavy undulations (Banning 2000).

Flakes: a piece of lithic material that does not display microblade characteristics, but has a definite point of impact as shown by a bulb of percussion on the ventral side of the proximal end, along with possible ripples and fissures moving away from the point of impact.

Shatter: lithic fragments that do not exhibit any or all of the characteristics to be defined as a flake, and are often small in size.

Attribute Analysis

For the attribute analysis of the sample assemblage, an Attribute Analysis Form (Appendix A) was created to record characteristics of each artifact that may have been the effect of natural or cultural activities. These attributes provided information about the manufacture and use of each object. The Attribute Analysis Form acted as a summary and solid starting platform to make suggestions and record thoughts on each artifact in order to provide a reference for future analyses. Sketches of both the dorsal and ventral surface of each artifact were recorded on the Attribute Analysis Form, along with the following traits:

Microblade Completeness:

Complete: both proximal and distal ends intact, often the overall form is curved

Distal fragment: only the distal end intact

Proximal fragment: only the proximal end intact

Medial fragment: neither proximal nor distal ends present, but otherwise identifiable as a microblade

Cortex: presence or absence, and on which surface. In this case cortex refers to the natural crystal growth faces, characterized by horizontal striations.

Termination style of the distal end: feather, hinge, or step, and NA (dorsal end was not present to analyze)

Proximal and distal cross section shapes: triangular, trapezoidal, or lenticular

Cross section was recorded and drawn on the Attribute Analysis Form for each tool. All microblades, including complete, proximal, distal, and medial fragments were included in the cross section analysis. When a microblade exhibited differing proximal and distal cross section shapes, the proximal cross section chosen to represent that artifact. The proximal end of the mircoblade is closest to the chosen point of impact and exhibits the shape which the manufacturer was most likely trying to achieve, and in which the material naturally breaks.

Microwear: absence or presence and location

Dimensions

Measurements of length, width, thickness, and weight were taken for each artifact. These measurements allowed for a direct comparison between artifacts within the sample assemblage and those measured by Walker (1999). To achieve a mean dimension, three measurement sets for length, width, and thickness were taken for each artifact using the same digital caliper with a precision of 0.01mm. The weight of each artifact was measured using a digital scale with a precision of 0.05 grams. Measurements were taken under the following parameters:

Length: Maximum dimension as measured along the longitudinal axis of artifact

Width: Maximum dimension measured perpendicular to length

Thickness: Maximum dimension of any part of the blade measured perpendicular to the length, generally located at the proximal end of the artifact

Microwear Analysis to Determine Location of Use and Haft Placement

Due to the quickly perishable nature of the organic materials used in hafting methods, hafts are not commonly found in association with their attached tools. Because of this lack of preservation, lithic analysts must rely on what was left behind on blade edges, such as microwear patterns and residues, to make inferences as to the functions of artifacts (Andrefsky 2005; Keeley 1980; Odell 2004). As none of the tools in the sample assemblage came with intact hafting materials, I resorted to microwear analysis and residue analysis to determine their functions.

History of Microwear Analysis

A major goal of microwear analysis is to determine tool function (Andrefksy 2005; Odell 2004). Microwear analysis was developed by Sergei Semenov in the 1960s when he discovered that differing wear patterns and polishes were formed on lithic tools depending on the raw materials they were used to process. Semenov viewed stone tools with an incident-light microscope and a stereomicroscope (Andrefsky 2005; Keeley 1980). Lawrence Keeley furthered Semenov's work by also identifying polishes and striations, and improving microwear analysis definitions and methods. Keeley (1980) assumes that when working different materials with lithic tools, specific microwear patterns to develop on tool edges. In turn, microwear patterns can help identify the material a tool was used to process. Modern experimental projects are used to recreate microwear in order to identify and better understand prehistoric microwear.

The three major types of microwear patterns that can be used to determine tool function are microchipping, striations, and polish (Andrefsky 2005). These wear patterns are caused by different processing behaviors. Microwear is caused by the use of a lithic tool against another material, striations are caused by the use of the tool against an abrasive material, and polish is caused by the frictional heat that is the result of vigorous and repeated motions of a tool against another material (Andrefsky 2005). For this thesis, I only recorded microchipping wear, which referred to below by the general term, microwear.

Microwear analysis methods involve the viewing of artifact edges for evidence of microwear, and can be separated into two different techniques: low-power, which uses tools such as a hand lens, stereomicroscope, or incident light microscope, and high-power, which uses a scanning electron microscope or an atomic force microscope (Andresfsky 2005; Kimball 1994; Kimball et al. 1995; Odell 2004). For this analysis, I used the low-powered technique.

Previous Microwear Analysis on Quartz and Quartz Crystal

Although studies of obsidian and cryptocrystalline varieties of quartz such as flint and chert, dominate microwear studies, a few researchers (Derndarsky and Ocklind (2001), Igreja (2009), Kimball (2008, 2013), and Sussman (1985, 1988), have deliberately chosen to examine macrocrystalline quartz and, to a lesser degree, quartz crystal.

Kimball (2008 and 2013) discusses high-powered techniques used to analyze microwear patterns on quartz artifacts. Kimball (2008) found polish on both lateral edges of a pièce esquillée which he believed was likely from bone sawing and also used as a wedge. Sussman (1985) describes the ability to view and identify differing microwear patterns on quartz crystal tool edges by viewing a sample of experimental tools with a scanning electron microscope (SEM) and an incident light microscope at high magnification. She utilized silver paint and a cement adhesive to mount her flakes. This adhesive may have contributed to the success of her analysis of using the SEM, in contrast to the difficulties I encountered, which are discussed further in this chapter. Sussman (1985) observed polish, striations, and other microwear, while Igreja (2009) observed only polish and striations on her experimental quartz crystal tools. Derndarsky and Oklind (2000) viewed fluorescent dyed experimental tools and artifacts with a confocal laser scanning microscope (CSLM) and were able to view surface and subsurface microwear patterns.

Igreja (2009) addresses the previously neglected topic of use-wear analysis of tools made of multiple varieties of quartz, including quartz crystal, by using experimental methods and differential interferential contrast microscopy (DIC). Side-hafted quartz crystal flakes were used in an experimental project to process a roe deer. Igreja observed that while striae and scars were visible, micropolishes did not develop on quartz crystal, but do on its related quartz and quartzite material types.

Goal of Microwear Analysis

Microwear analysis will contribute to the investigation of quartz crystal microblade use by determining: (1) most commonly used edge, (2) potential hafting placement, and (3) scarring types/patterns. The most commonly used edge was identified by the presence of microwear patterns, with special attention paid to corresponding lateral and lateral vs distal wear patterns that may indicate hafting placement. All edges of artifact in the assemblage were viewed at multiple magnifications using a hand lens and a stereomicroscope/dissecting microscope. Analysis took place in the WWU Department of Anthropology's Archaeology Laboratory or in dedicated microscope laboratories in the Biology Department.

Three microscopes with varying levels of magnification were utilized in this analysis: a hand lens, stereomicroscope, and dissecting microscope. When possible, scales were included in photographs at each stage of magnification to allow for an accurate comparison and measurement of use-wear patterns. Often, these scales could not be viewed due to magnification levels or sizes of use-wear patterns and so were digitally added to the photographs after analysis.

The levels of magnification used were unique to each microblade, as some microwear patterns were easily identifiable at a lower level of magnification, while others needed to be examined further to definitively identify the scar pattern and orientation. An illuminated hand lens (20x) was used during the preliminary, morphological analysis. The microwear scarring patterns originally recorded on the Attribute Analysis Form were fairly accurate in identifying the presence and location of microwear. Further magnification and analysis allowed for specific scar types, patterns, locations, and orientation to be identified, and occasionally previously unidentified wear patterns to be recorded.

I used both an Olympus SX61 stereomicroscope with a magnification of up to 45x and an Olympus CX41 dissecting microscope with a magnification of up to 100x equipped with an interchangeable digital camera. This camera allowed for an additional level of confidence, as I can provide visual documentation of microwear patterns for each tool, rather than just descriptions. Microphotographs also assisted in analysis by permitting me to review previously analyzed microblades without requiring re-observation. This allowed for a level of comparison of the microwear patterns between individual blade edges which would not have been as easily provided without this technology. Sussman (1985) viewed her samples a minimum of two times for her analysis, as did I in this analysis.

These microscopes provided a wide array of valuable data, but they also came with challenges. The stereomicroscope has a magnification range and field of view that included most of the length of the lateral edges, while still allowing an adequate amount of zoom to see more details on flaking patterns and residues. Unfortunately, this microscope is not equipped with lighting, so illumination of the sample was done solely with manual LED lights. The dissecting microscope provides a greater magnification and is equipped with lighting, but usable levels of magnification were varied and often limited due to the thickness of the quartz crystal artifacts. Samples would have to be much thinner to view while avoiding contact with the lens piece.

Complete Blade Analysis Attribute and Location Definitions

Complete microblades provide the most data in regards to my research goals because they allow for the identification of complete possible edge use and haft placement. In order to better understand potential locations of use and placement of quartz crystal microblades in hafts, all complete microblades (n=28) were closely analyzed and photographed with the stereomicroscope and/or dissecting microscope. Hafting methods used can be inferred based on the placement of scar patterns along a tool edge. Hafting analysis can both deduce how the tools were mounted, and make inference as to tool function based on the potential capability or restrictions of the amount of exposed lithic edge.

To be able to relate locations of wear within and between microblades, I conceptually separated both the left and right lateral blade edges into 3 equal portions. While the distal end was included, the proximal blade edge of the artifacts was not included within the microwear analysis as it was too difficult to determine if the wear was caused during preproduction, by crushing on platform preparation, or during postproduction by utilization.

To enhance and easily visualize the microwear present on blade, a grid separating each tool into portions was overlaid on a photograph of the blade during analysis (Figure 9). Each blade portion was viewed and photographed at a variety of magnifications and described on a Microwear Analysis Form (Appendix B). The relationships between the presence and absence of microwear patterns indicates where a haft would have been situated along the blade edge.

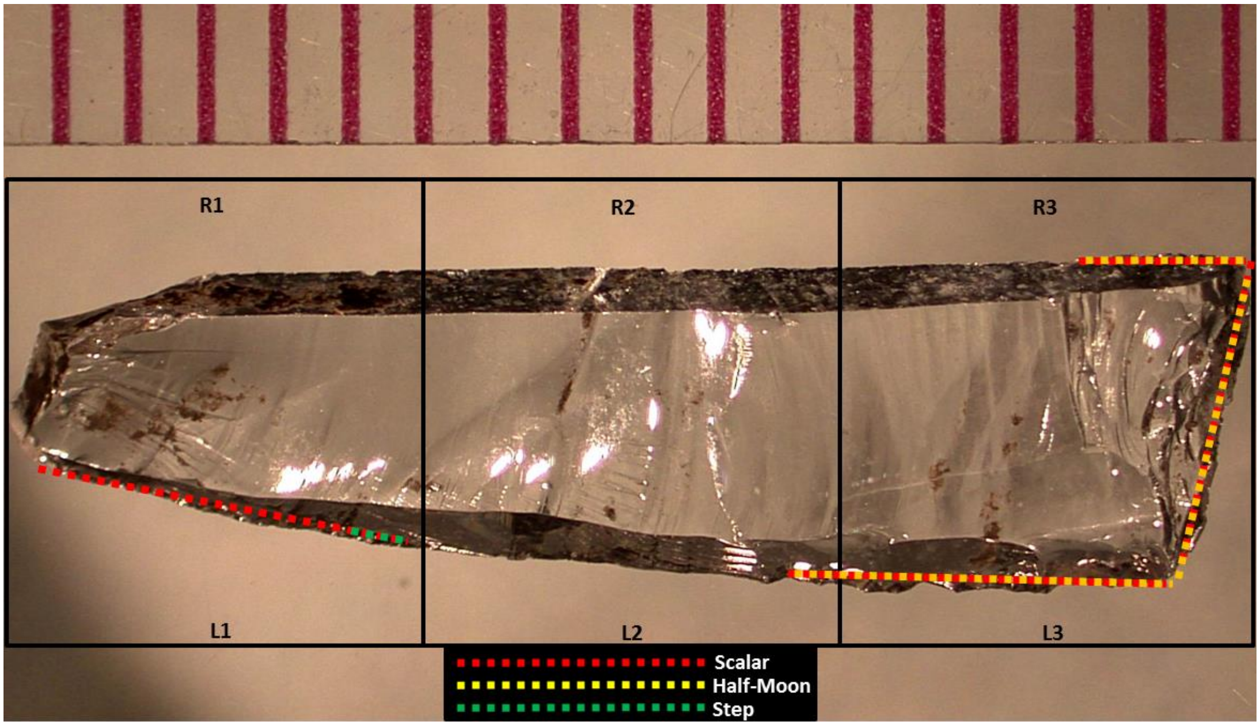


Figure 9. Example of complete blade microwear analysis on Artifact #1591 from 45WH55 with differing wear patterns shown by color-coded dotted lines.

The lengths of R1/L1, R2/L2, R3/L3, and D are unique for each complete blade as each tool was divided into even thirds. The divisions allow for a comparison of the proximal, medial, distal lateral edges, along with the distal tip. This arbitrary length assignment is adequate for analysis assuming that they are comparable portions and that exact length of these portions would have been important to prehistoric peoples.

I used microwear criterion developed by Greaves (1991) which requires modification to be continuous for a minimum of two negative flake scars, or a distance of 2mm to be considered microwear. Each of the following microwear attributes was recorded for the 7 separate edge portions of the complete blade subsample of the sample assemblage:

Microwear (present or absent)

Scar Type (Scalar, Half-Moon, Step) (Keeley 1980:24) (Figure 10)

Scalar- scale shaped scars

Half-moon- crescent-shaped breakages

Step- abruptly terminated scars, with edges directly perpendicular to blade edge

Combination patterns of scar types were also recorded. If scalar and step scars occurred together in a single portion, even directly overlapping, they would be recorded as SCST (Figure 11). If different scar types occurred in spatially distinct areas within a single portion, they would all be indicated, separated by a (/). In other words, a designation of SC/ST indicates a section of scalar scars and then a distinct section of step scars. The two sections could be adjacent or there could be a gap with no wear. The (/) could also be used to indicate distinctly different scar patterns of the same scar type, for example two sets of scalar scars of different size or orientation along the same blade edge portion were recorded as SC/SC (Figure 12).

Orientation of microwear (perpendicular or oblique to blade edge)

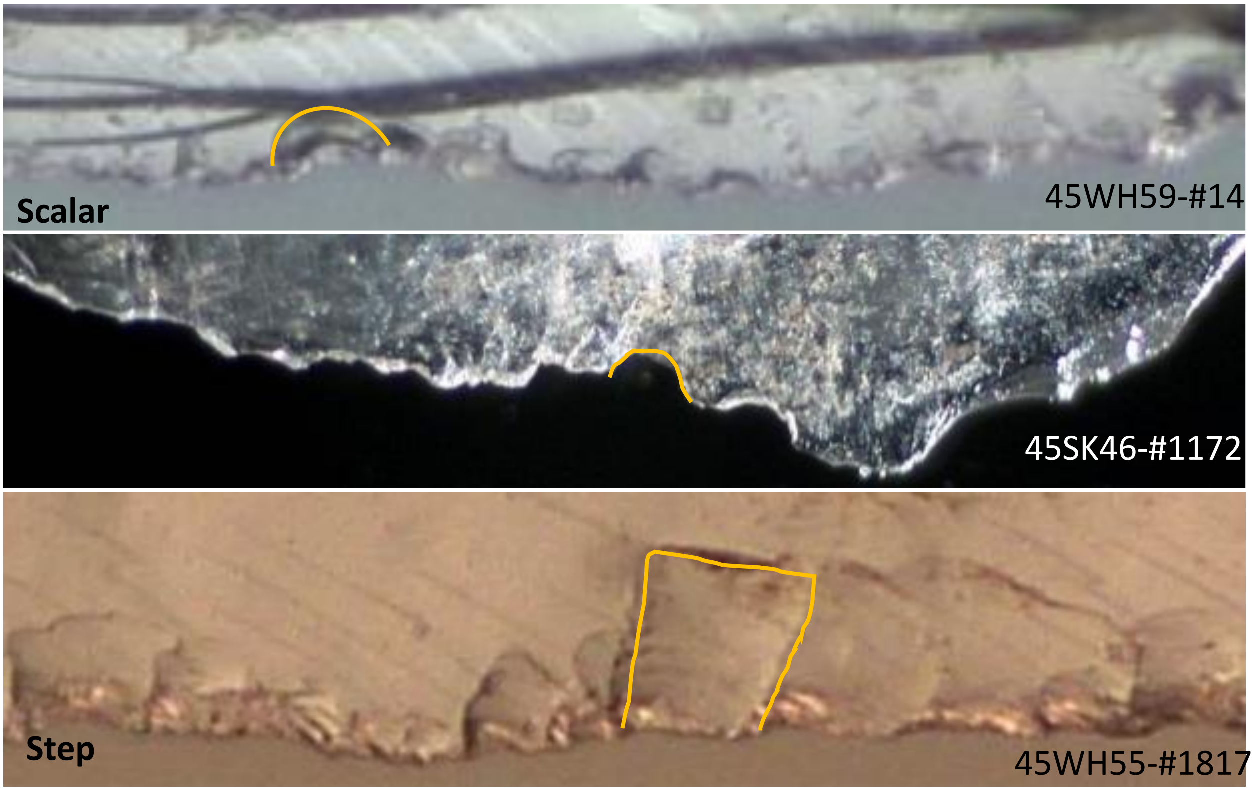


Figure 10. Examples of scalar, half-moon, and step scar types.

Figure 11. Example of scalar and step combination scar pattern (SCST) (45WH55-#1817).

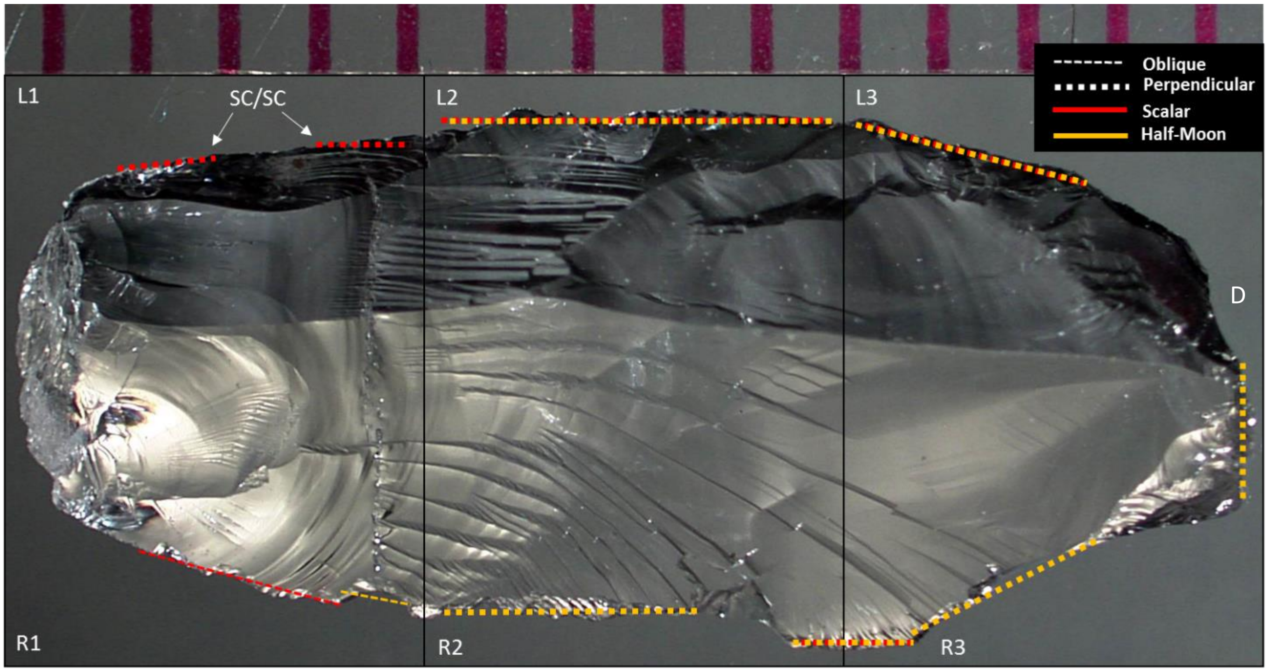


Figure 12. Example of SC/SC scar pattern (L1) (45SK46-#1166).

Expectations of Microwear Patterns

Assumptions and expectations about microwear patterns on the edges of microblades are based both on studies of general lithic technology (Andrefsky 2005; Odell 2004) and from specific examples of microwear and hafting from the Northwest region (Croes 1995; Goebel and Buvit 2011; Helwig et al. 2008; Walker 1999). Reviewing examples of hafted microblades from the same time period and region as the sample assemblage allowed me to suggest where hafting material on tools in the sample assemblage would have been placed. The single hafted quartz crystal microblade from the Hoko River site is end-hafted. Its presence does not limit quartz crystal microblades to only this hafting method, but it is a useful example of a hafting style. Flenniken (1981) believes that despite their different methods of manufacture, microblades and microliths were likely hafted in the same fashions.

Based on microwear analysis, Walker (1999) concluded that quartz crystal microblades from 45CA426 were end-hafted. This assumption was based on the observation of microwear on both lateral edges, and more commonly on the distal rather that proximal blade portions, along with the presence of microblades with broken distal tips.

The presence of microwear on a blade portion suggests use, while a lack thereof suggests it was not exposed to or was covered by hafting material during use. The occurrence of two distinct areas of microwear, or microwear and then an absence thereof on a single lateral edge, suggest a partial covering (by hafting material) or the choice to use that specific edge portion. Microwear along one entire lateral edge, with an absence or different form of microwear on the opposite lateral edge suggests the blade was side hafted. End hafting would be indicated by finding wear patterns on the distal tip and possibly one or both distal portions of the right and left lateral edges. Microwear found on just the distal end would suggest a finer and more specific cutting style than microwear found on the entire edge or multiple edges of a tool.

The expectations for connecting microwear patterns to hafting styles are as follows:

End Hafted Microblades: will show microwear on the distal tip (D), with additional microwear patterns along one or both most distal lateral edges (R3/L3), starting at the junction of the distal tip and lateral edge and moving upwards towards the proximal end. These microwear patterns should show a distinct separation between what would have been the portion of the lateral edge covered by hafting material and that of the exposed blade edge(s).

Side hafted microblades: will have distinct microwear patterns on a single or both lateral edges, with microwear patterns covering the majority of the lateral edge with limited distal end wear. Side-hafting would have allowed the total lateral edge to be utilized and microblades may have been rotated to expose a new lateral edge previously hidden by the haft.

It is important to take the general topography of a tool into consideration when viewing tool edges for microwear. Natural ripple marks and fissures caused during the removal of a microblade from its core may be mistaken as a microwear pattern where they intersect the blade edge. The placement and extent of microwear, along with the presence of general morphological features were taken into consideration for each individual tool.

Ventral and dorsal surfaces were viewed at multiple levels of magnification during the analysis. Due to the clarity of the material, it was difficult to determine ventral versus dorsal microblade edge wear, and because of this, the location of wear was separated only by blade portion and not blade face. Abrasion or microwear patterns suggesting haft placement on other portions of the ventral and dorsal surfaces were not observed.

Experimental Projects

During experimental analysis, it is difficult to replicate and test every potential processing behavior with pressure and angle variables (Keeley 1980). This limits the abilities of functional experimental projects, and makes reaching reliable conclusions about function difficult. Additional challenges occur during attempts to separate or replicate layered wear patterns that might arise from multiple uses. It is a large task to exhaust all possible processing activities, while controlling conditions for material, force, angle, and direction. In the case of quartz crystal microblades, additional hafting variables also need to be considered. After considering the number of variables that would have to be controlled and tested for, I decided that an exhaustive, formal experimental project fell outside the scope of this research.

Production Wear and Post-depositional Surface Experimentation

Andrefsky (2005), Grace et al. (1985), and Odell (2004) have discussed problems posed by post-depositional surface modification (PDSM). Edge damage can take place during artifact processing and cataloging in either the field or laboratory, or both. To improve my ability to identify PDSM and edge damage caused during production, I performed a small experimental production project. The manufactured tools were analyzed in order to make comparisons to the sample assemblage.

During the production experiment, multiple microblades were removed from a quartz crystal core. Methods of blade removal were guided by Lagestee (2012), Reher and Frison

(1991), Sussman (1988), and Walker (1999), and included the use of a vise and application of indirect percussion. First, the platform was prepared by abrasion with a metal file until it was a fairly flat striking surface. Next, a vise was placed on the core and then held between my feet while sitting on a tile floor covered with a piece of leather. Finally, microblades were removed when a sharp and forceful strike with a wooden mallet was applied against a copper tipped percussion flaker. The flaker was placed at an approximate 45° angle, slightly inward on the core's platform, directly above a natural crystal ridge.

The blades produced during the experimental project were immediately viewed under a microscope. No scarring patterns were observed on the blade edges, with the only exceptions being occasional single, large, scalar or half-moon scars. These scars were likely produced when the stone broke along an impurity, or when the blade dropped from the core to the leather covered floor below it.

For comparison, I looked at other replicated microblades that had been housed for at least a year under similar conditions as the archaeological sample assemblage. These quartz crystal microblades were produced by Todd Lagestee, who presented results of his experimental analysis at the Northwest Anthropological Conference in March of 2012. Lagestee's goal was to better understand quartz crystal core reduction and microblade production. He attempted a variety of production methods and was successful when using modern materials and tools in the knapping process. He did not utilize any of the manufactured microblades, so it is assumed that any microwear on microblade edges occurred either during production, or after being stored in bags. Lagestee's microblades, flakes, and debitage were collected in plastic bags similar to the ones used in WWU's Archaeology Laboratory and were donated to Dr. Sarah Campbell.

I compared three freshly manufactured microblades to four of Lagestee's bagged microblades. The edges of both sets of microblades were viewed microscopically to better understand the edge damage incurred during curation. The damage observed consisted of minimal, small, disorganized, jagged scars, very different from cultural wear patterns which have repetitive and identifiable scar types. PDSM or "bag-wear" is very distinct from the cultural wear patterns which I observed on artifacts in the sample assemblage (Figure 13). Scattered medium to large step and scalar scars, likely from production were also seen on Lagestee's microblades.

This direct comparison allowed me to confidently separate wear patterns into those associated with prehistoric use and production and those arising from modern curation practices. PDSM wear was observed, but not recorded, on artifacts from within the sample assemblage. This wear was usually continuous along the whole, and sometimes multiple blade edges. In comparison to microwear patterns such as scalar, step, and half-moon scars (Keeley 1980), PDSM wear appeared as small, jagged scar patterns, with less definition or extent onto the microblade face. I do not believe the presence of PDSM obscured my ability to identify microwear patterns from blade use; it did not extend far enough from the edge to obscure larger flake scars. PDSM was most recognizable on blade edges that otherwise had no microwear. Little difference was noticed between the PDSM between site assemblages despite their differing dates of excavation and original curation and collection techniques.

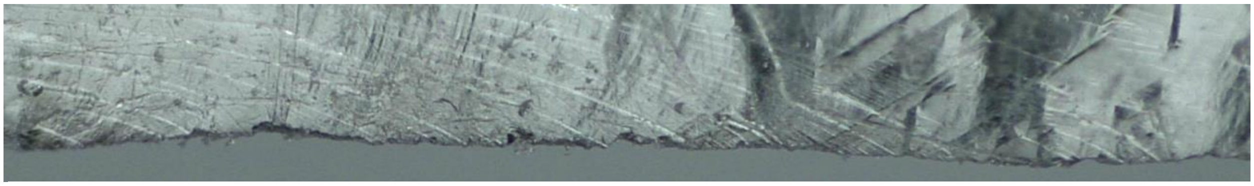


Figure 13. Post depositional surface modification along experimental tool edge.

Residue Analysis

Residues on microblades allow inferences to be made about their use in prehistoric processing behaviors. Two methods were used to analyze residues on the surfaces and edges of a subsample of the sample assemblage: energy-dispersive x-ray spectrometry using the scanning electron microscope (SEM-EDX) and cross-over immuno-electrophoresis (CIEP).

Residue analysis began with observing the entire sample assemblage using a hand lens, and recording colors of residues viewed on an Attribute Analysis Form. Next, these residues were viewed and photographed at a variety of levels of magnification using a stereomicroscope and dissecting microscope. Greater magnification levels allowed for the viewing of residues more clearly, and for a better understanding of their density on the artifact. I did not use a standardized color classification system, such as Munsell's, because it was not possible to fit color scales beneath the microscope lens at the same time as samples. I assigned common color categories visually, and was able to be consistent and note minor color variations.

Attribute and microwear observations at differing magnifications allowed me to select which tools should be further analyzed using inorganic and organic residue testing methods. Twenty-three artifacts were tested for the presence of inorganic compounds using a scanning electron microscope equipped with an energy-dispersive x-ray spectrometer (SEM-EDX) and 25 quartz crystal microblades were tested for organic residues using the cross-over immune-electrophoresis (CIEP) technique.

Energy-dispersive X-ray Spectrometry (SEM-EDX)

The Vega TS 5136MM scanning electron microscope equipped with an EDAX Energy Dispersive X-Ray Spectrometer (EDX) and Retractable Backscatter Detector (BSE) available at Western Washington University Scientific Technical Service's SEM instrument laboratory allows a magnification of 1,000-150,000x (Flegler and Klomparens 1995). Odell (2004) suggests that it is not feasible to process an entire assemblage through the scanning electron microscope, and such is the case with the sample assemblage. The data gained from this analysis was beneficial, but there were many time constraints and difficulties associated with imaging such a pure mineral. Artifacts often collected a charge and required multiple imaging attempts. The insertion and changing of artifacts in and out of the SEM chamber was also much more time consuming than using other microscopes. Due to these challenges, only a subsample of the sample assemblage (n=29) were viewed using the scanning electron microscope. The SEM was used for limited viewing and photographing of artifact surfaces and edges at extremely high magnifications.

An energy-dispersive x-ray spectrometer (EDX) was utilized for the analysis of inorganic residues on 23 of 29 analyzed quartz crystal artifacts. SEM-EDX allowed for the identification of the elemental composition of each artifact, along with that of any residues on their surfaces. Compositional readings were taken on proximal, medial, and distal sections for each artifact to confirm that the artifact was indeed SiO_2. Areas that appeared to have adhered residues were also tested. These areas were easily identifiable as they reflected less of the electron beam and exhibited a different texture than the rest of the artifact under SEM magnification.

The use of the scanning electron microscope was challenging due to the fact that quartz crystal collects a charge when exposed to the electron beam (Figure 14). This charge obscures visibility and does not allow for images to be taken. It also makes targeted composition analysis difficult. To limit or avoid the buildup of a charge, I moved as quickly and efficiently as possible as soon as the artifact was exposed to the beam. To deflect some of the charge away from artifact surfaces, I produced mounts by attaching an aluminum foil pocket to an aluminum plate with copper tape. The aluminum foil and copper tape attracted some of the charge away from the artifact being analyzed. The pockets also held the artifacts in place and allowed for them to be tipped within the chamber. This permitted viewing and compositional analysis of artifact residues from additional angles. I also experimented with varying levels of beam power and a variable pressure mode to help eliminate some of the charge on the samples. I was most successful with a combination of these, but the level of aluminum covering, tilt, and the use of the retractable backscatter detector was unique for each analyzed artifact.

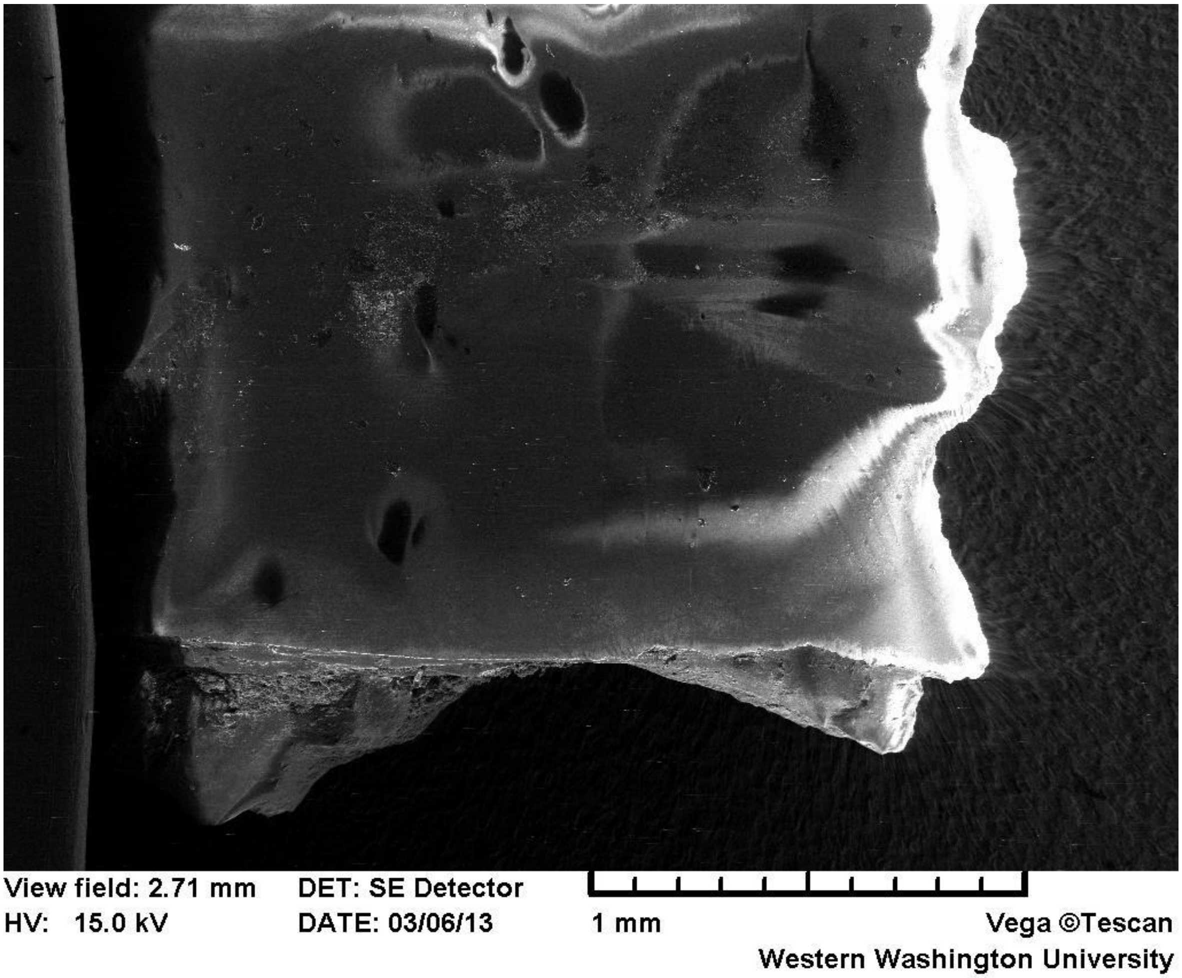


Figure 14. Quartz crystal microblade collecting a charge while being exposed to the electron beam of a scanning electron microscope.

Cross-Over Immuno-electrophoresis (CIEP) Analysis

Cross-over immuno-electrophoresis (CIEP) was originally used to assist in crime investigations before present day DNA fingerprinting methods were available. The use of CIEP testing to assist with archaeological analysis began in the 1980s when Dr. Margaret Newman, at the request of David Hurst Thomas, analyzed projectile points from the Hidden Cave site of Northwestern Nevada (Thomas 1985). This method continues to be an important part of archaeological analysis and has been labeled the “most effective extractant for old and denatured proteins without interfering with subsequent testing” (CSUBLAS 2014).

CIEP residue analysis occurs in multiple steps (CSUBLAS 2014). First, each artifact is placed in a separate container where a solution of 5% ammonium hydroxide is applied directly onto its surface. This solution breaks the hydrogen bond between the stone tool and the proteins attached. The solution, and an individual soft brush used to rub it on each tool, removes residues from the artifact’s surface, along with the proteins trapped in its microfissures. Next, the artifact and solution are disaggregated using an ultrasonic cleaning bath, collected, and then cooled.

CIEP traces the immunological or “allergic” response of foreign proteins. To cause this response, a known antiserum and the unknown solution are injected into horizontally adjacent wells in a prepared agarose gel template. Next, the gel is placed in an electrophoresis tank filled with barbital solution and subjected to an electric current. This agitation encourages a reaction between the known and foreign proteins and causes them to migrate between the wells. This response is marked by a one, or two “precip lines” that are invisible until the gel is pressed, dried, and stained. The gels must be carefully analyzed as reactions occur at a variety of levels, leaving a range of visible precipitation lines. CIEP analysis identifies residues at the family level which can lead to suggestions as to which species was likely present as residue on the artifact. Positive controls are utilized throughout the process to assure accuracy (CSUBLAS 2014).

I tested a subsample of the sample assemblage using the CIEP process at California State University, Bakersfield's Laboratory of Archaeological Sciences (CSUBLAS). The goal of this non-profit laboratory is to assist archaeological researchers in performing analyses and with the knowledge that can be obtained from the process. The lab also experiments with the refinement of the CIEP technique as whole (Robert Yohe, personal communication, November 2013).

CIEP Sample Selection

A sample of 15 quartz crystal microblades that exhibited visible residues and microwear patterns were selected from the sample assemblage for CIEP analysis (Table 2). Within the sample was artifact #760 from site 45WH59, a complete microblade with a red ochre-covered distal tip. It was unclear as to how many visible residues would be removed during the CIEP process. Because of this, the surfaces of each artifact were thoroughly photographed at a minimum of two levels of magnification before the testing. I personally transported the selected artifacts to CUBLAS and assisted with the CIEP analysis. All 15 artifacts were tested using the same methods and controls. The exception was artifact #760, which was not exposed to the ultrasonic bath, but rather manually agitated because of the sensitive red ochre covering the blade's distal tip. The tip and remainder of the blade were tested separately to determine if the tip had been exposed to different proteins than the rest of the artifact.

After processing the first set of samples, Dr. Yohe offered to test an additional set of 10 artifacts (Table 2). Due to a limited success from the original set of 15, I chose different qualifications for the next set of samples. Selections for the first sample set primarily focused on the presence of visible residues, so for the second set, the presence of microwear took priority. Some of the microblades chosen did not exhibit any visible residues, but did have extensive microwear scarring patterns on their blade edges. The cost of the CIEP residue analysis caused some constraints, but the sample of 25 artifacts (33% of the assemblage) allowed for a good representation of the residues associated with these tools.

Table 2. Artifacts selected for CIEP analysis.

Site #	Artifact #	Description
45SK46	407	Microblade
45SK46	1163	Microblade
45SK46	1164	Microblade
45SK46	1165	Microblade
45SK46	1166	Microblade
45SK46	1168	Microblade
45SK46	1171	Flake
45SK46	1172	Microblade
45WH1	54	Microblade
45WH1	119	Microblade Fragment (Proximal)
45WH1	179	Microblade
45WH17	1344	Microblade
45WH55	507	Shatter
45WH55	612	Flake
45WH55	707	Microblade
45WH55	760a	Distal Tip of Blade
45WH55	760b	Remainder of blade
45WH55	1147	Microblade Fragment (Medial)
45WH55	1565	Microblade (Proximal)
45WH55	1817	Microblade
45WH59	9	Microblade Fragment (Medial)
45WH59	15	Microblade
45WH59	16	Microblade
45WH59	31	Microblade Fragment (Proximal)
45WH59	36	Microblade Fragment (Proximal)
45WH59	37	Microblade

Botanical Analysis and Radiometric Dating

Spear (1977:93) suggested 45WH59 dated between 5500 and 3000 BP based on the presence of microblades but no radiometric date had been obtained. Selected charcoal samples recovered from 45WH59 in association with quartz crystal artifacts were chosen to be radiometrically dated. Units at the site with multiple quartz crystal artifacts were identified, and then checked against the site catalogue for charcoal samples from the same units. Only 17 charcoal samples had been collected, and only 2 from units with quartz crystal artifacts; both charcoal samples were selected for radiometric dating.

The first charcoal sample (Cat #64) was collected from N1W1, which yielded 7 quartz crystal artifacts, and the second sample (Cat #22) was collected from N1W2, with 8 quartz crystal artifacts (Table 3). These adjacent units had similar stratigraphy, with quartz crystal artifacts found at the same depths as the charcoal samples, as well as depths above and below. Neither piece of charcoal was recovered from a hearth feature, but profile drawings show intermittent small charcoal lenses in the "B-horizon" in which the samples were collected (Spear 1977). In the A-horizon layer above the B-horizon, Spear (1977) describes charcoal in a humic mineral soil which he believes is a product of brush and root fires. There was no indication, however, of any intrusive burned roots in the B-horizon. Profile drawings of N1W1 and N1W2 are located in Appendix C.

Table 3. Samples from 45WH59 chosen for radiometric dating.

Site #	Catalog #	Cut	Unit	Level	Depth
45WH59	22	N1W2	A	40-60cm	56cm
45WH59	64	N1W1	C	40-60cm	56cm

The first charcoal sample (Catalogue #64), was recovered on 5/27/1976 from N1W1, unit C. It was removed within the 40-60 cm level (56cm) in soil described as 5 YR 3.4. The layer in which the sample was collected is described on a profile map of the east wall of N1W1 and field notes as the “Red Lynden Loam” layer, a reddish silty-sand layer with lenses of charcoal. The excavation of N1W1 is described in the field notebooks of Donald J. Pint and Gene Woodruff from 5/13/76-6/3/76. Eight artifacts, including 4 of quartz crystal, were recovered from the 40-60cm layer, and 2 quartz crystal artifacts were recovered from the 60-80cm level (Table 4).

Table 4. Artifacts from cut N1W1, 45WH59, associated with charcoal sample (Catalog #64) from site catalogue and field notes.

Cat #	Artifact Type	Unit	Depth (cmbs)	Munsell	Association
54	Spall tool /cobble tool	E	42cm	5 YR 2.5/2	With charcoal lens
57	Quartz crystal microblade	E	40cm	5 YR 3/4	In close proximity to #54 and charcoal
-	2 wood objects/fragments	B	52cm	-	-
60	Quartz crystal microblade	H	46cm	5 YR 2.5/2	In direct association with small lenses of charcoal
56	Basalt microblade	A	52cm	5YR 3/3	-
62	Quartz crystal microblade	A	56cm	-	With #63 and within a charcoal layer and at the exact same depth as the charcoal sample in unit C
63	Quartz crystal microblade	A	56cm	-	With #62 and within a charcoal layer and at the exact same depth as the charcoal sample in unit C
65	Quartz crystal artifact	A	55cm	-	-
67	Quartz crystal microblade	A	61cm	5 YR 3/2	In association with charcoal sample (#64) and two small lenses of “burnt” soil.
74	Quartz crystal microblade	D	72cm	5YR 2.5/2	In charcoal lens and bunt soil

The second charcoal sample (Catalog #22), recovered on 4/30/1976 from N1W2, unit A (Table 5) was removed within the 40-60 cm level (56cm). The layer in which the sample was collected is described on two profile maps, one of the east wall and one of the north wall of N1W1, and in the field notes as the “Red Lynden Loam” layer, a reddish silty-sand layer with lenses of charcoal. The excavation of N1W2 is described in the field notebooks of Diane K. Hanson and Kevin Jacques from 4/15/76 through 5/21/76.

Table 5. Artifacts from cut N1W2, 45WH59, in association with charcoal sample (Catalog #22).

Cat #	Artifact Type	Unit	Depth (cmbs)
3	Quartz crystal core fragment	D	43
5	Flake	C	50
9	Quartz crystal microblade fragment	C	51
11	Quartz crystal microblade fragment	F	49
15	Quartz crystal microblade	I	54
16	Quartz crystal microblade	C	54
17	Quartz crystal microblade fragment	F	51-55
18	Basalt microblade	C	55
21	Projectile point	A	56
25	Quartz crystal microblade fragment	F	59

In January 2014, Deborah Ann Gahr performed a botanical analysis to determine the makeup of two charcoal samples from 45WH59 (Appendix D). The samples were then analyzed using radiometric dating techniques in February of 2014 by Beta Analytic Inc. in Miami, Florida. Catalogue #22 was described by Gahr (2014) as a mix of sediment and charcoal pieces measuring less than 0.5mm, along with “parenchyma tissue such as from geophytes, herbaceous dicot (hardwood) bark, conifer (cf. *Tsuga* sp. and unidentified conifer).” Gahr showed concern for the presence of root hair intrusions in this sample. She removed some, but not all of these intrusions, and their presence was noted when the samples were sent away for radiometric dating. The sample was sent to Beta Analytic Inc. and resulted in a modern date of 330 ±30BP using AMS dating techniques (Beta Analytic Inc. 2014) (Appendix E). Gahr (2014) identified Catalogue #64 as Douglas fir (*Pseudotsuga menziesii*). Radiometric dating of this sample resulted in a conventional date of 2760 ±30BP (Beta Analytic Inc. 2014).

CHAPTER 5: RESULTS

The methods described in the previous chapter were successfully applied to the sample assemblage, or in some cases to selected subsamples. This chapter presents the results of these analyses beginning with morphological analysis, followed by sections on microwear and residue analyses.

Morphological Analysis

The frequencies of quartz crystal object types by site are shown in Table 6. Of the 68 artifacts in the sample, the most common object type was microblades (68%), followed by cores (12%), flakes (13%), medial fragments (10%), and finally shatter (7%). Among the microblades, complete blades were the most frequent (61%), followed by proximal fragments (24%), and finally medial fragments (15%) (Table 7). No distal fragments were recorded. Raw attribute data can be found in Appendix F.

Table 6. Total counts and percentages of artifacts in the sample assemblage.

Site #	Core	%	Microblade	%	Flake	%	Shatter	%	Total
45SK46	0	0%	8	67%	1	17%	2	17%	12
45WH01	1	25%	3	75%	0	0%	0	0%	4
45WH17	1	100%	0	0%	0	0%	0	0%	1
45WH47	1	100%	0	0%	0	0%	0	0%	1
45WH55	0	0%	7	78%	1	11%	1	11%	9
45WH59	5	12%	28	68%	6	15%	2	5%	41
Totals	8	12%	46	68%	9	13%	5	7%	68

Table 7. Total counts and percentages of types of microblades in the sample assemblage.

Site #	Complete	%	Proximal Fragment	%	Medial Fragment	%	Total
45SK46	7	88%	1	13%	0	0%	8
45WH01	2	67%	1	33%	0	0%	3
45WH55	5	71%	1	14%	1	14%	7
45WH59	14	50%	8	29%	6	21%	28
Totals	28	61%	11	24%	7	15%	46

In the sample assemblage complete blades are the most common, at 61%, followed by proximal fragments (24%) and medial fragments (15%). In contrast, at 45CA426, proximal fragments were the most common portion type at 38%, followed by complete blades at 34%. Medial and distal fragments each made up 14% (Walker 1999:14.5). Distal microblade fragments were not present in the sample assemblage

Walker (1999) describes a core rejuvenation flake as a flake removed from the platform of an exhausted core, or the removal of the entire platform in order to prepare the core for additional flake removal. I was unable to define any artifacts in the sample assemblage as core rejuvenation flakes.

As expected, artifact richness increases with sample size, with 45WH59 having the largest overall quantity of quartz crystal artifacts, along with artifacts from all 4 object types. Screen size may be a factor in overall sample sizes. The second and third largest assemblages, 45SK46 and 45WH55, rank after 45WH59 in richness, with three object types each. Both of these sites were excavated using 1/8” screen. Before the 1980s screen mesh size was typically 1/4”, which would affect recovery rates of quartz crystal microblades, which are small as well as being difficult to see because of their clarity. Because cores are generally larger than the microblades, they would be less affected by screen size bias, this may account for the recovery of only cores at 45WH17 and 45WH47. However, the same screen size was used at 45WH59, where a larger range of artifacts was recovered. Perhaps differences in the sediment affected visibility, or excavator awareness early in the project led to great recognition but there is no direct indication of this in the field notes.

Comparison to Spear's (1977) Analysis of 45WH59

Spear (1977) previously analyzed the quartz crystal artifacts from 45WH59; there are some differences between his results and those in this thesis. The author described and measured three "quartz" microblade cores from site 45WH59 while I recorded 5 cores, including artifact #176, which was labeled by Spear (1977) as a proximal microblade section, but appears to be a split crystal fragment with a small negative microblade scar on one cortical surface. Nonetheless, the overall measurements obtained in both analyses are similar (Table 8). I also analyzed all 26 quartz microblades included in Spear's (1977) analysis, along with 2 additional microblades. These were catalogued artifacts and I am unsure as to why they were not included his analysis. Spear's morphological categories differ from this analysis, and his criterion for microblade fragment categories are not defined (Table 9).

Table 8. Comparison of 45WH59 core measurements taken by Spear (1977) and this analysis.

Measurement		Spear (1977)	This Analysis
Length	**Range**	.83-1.5	.75-1.51
	Mean	1.18	1.16
Width	**Range**	.73-1.19	.70-1.2
	Mean	0.9	0.95
Thickness	**Range**	.43-.66	.43-.57
	Mean	0.54	0.52

Table 9. Comparison of 45WH59 microblade categories, Spear (1977) and this analysis.

Microblade Category	Spear (1977)	This Analysis
Complete Blade	0	14
Proximal Fragment	14	8
Medial Fragment	10	6
Distal Fragment	2	0
Total	26	28

Dimensions

Microblades are removed from microcores, so dimensions of different object types provide information on the initial size of cores, the amount of reduction, and the likely desired dimensions of microblades (Figure 15). Complete raw metric data from the three sets of dimension measurements is provided in Appendix G. Measurements provided by Walker (1999) allowed for a direct comparison between the cores and microblades in the sample assemblage to those from site 45CA426.

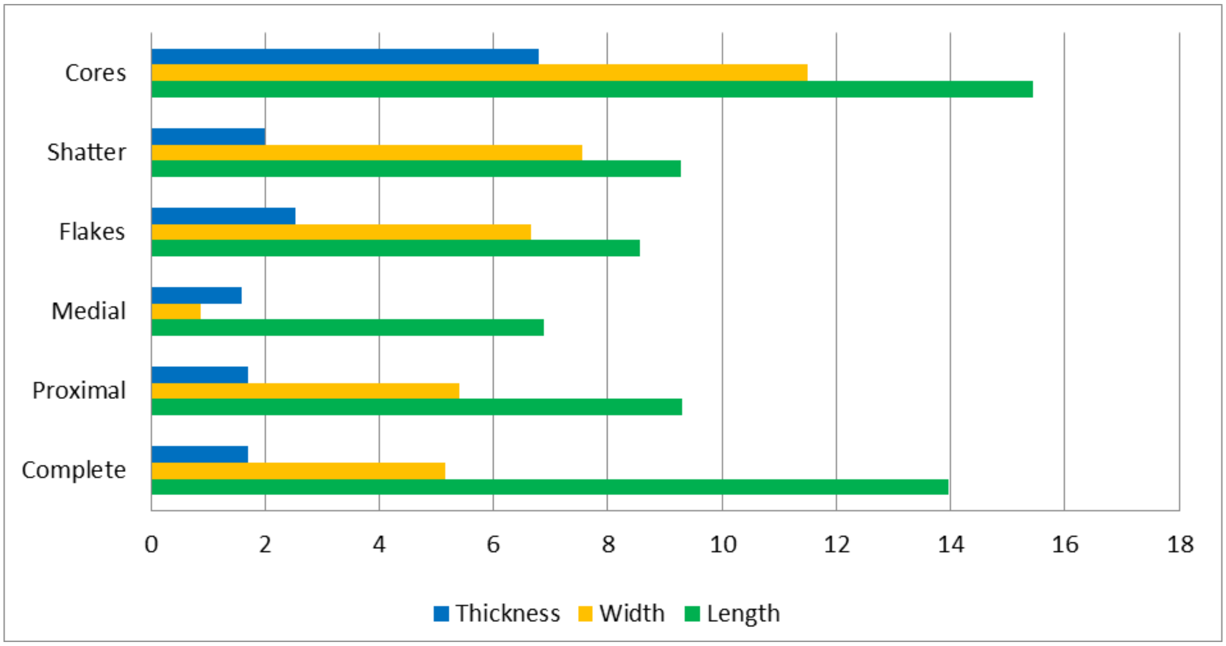


Figure 15. Mean lengths, widths, and thicknesses for artifacts in the sample assemblage (mm).

The mean weight of the six core artifacts measured by Walker (1999) was 4.02 g while the same measurement of the eight cores in the sample assemblage was 2.12 g (Table 10). Both of the sample sets had a large range, with Walker's (1999) at 6.1 and the sample assemblage at 7.7. Walker (1999) measured the "height of core" which is comparable to the sample's core length measurements. Three of her measurements, noted with an asterisk, were included in the data table, but were labeled incomplete. These measurements were still included within the mean length comparison. The mean length measurements of the sample assemblage of cores in comparison to Walker (1999)'s differed by only 2.44 mm.

Table 10. Core measurement comparisons between the sample assemblage and 45CA426 (Walker 1999).

Site #	Artifact #	Length (mm)	Weight (g)
45WH01	1275	22.83	7.89
45WH17	1435	26.31	3.83
45WH47	61	16.35	0.96
45WH59	3	7.77	0.43
45WH59	27	14.86	1.32
45WH59	33	10.73	0.82
45WH59	41	14.8	1.51
45WH59	176	9.86	0.19
Average	**-**	**15.44**	**2.12**
45CA426	5411	26.67	6.5
45CA426	5946	23.74	5.2
45CA426	6001	10.84*	0.5
45CA426	6027	14.24*	0.4
45CA426	6110	22.72	11
45CA426	7471	9.04*	0.5
Average	**-**	**17.88**	**4.02**

The measurement of core lengths and weights for the sample assemblage were statistically analyzed and compared to those included in Walker (1999) using t-tests. The core length measurements of the two samples were not significantly different from one another (t=.659, p=.346). Core weight measurements were also not significantly different between the two samples (t=-1.028, p=.104).

Differences in the length, width, and thickness of microblade artifacts from 45CA426 and the sample assemblages were also tested (Table 11). The length (t=4.762, p=4.43736E-06), width (t=2.062, p=0.04) and thickness (t=-4.573, p=6.38594E-06) of microblade artifacts in the two assemblages were significantly different from one another. The overall results of statistical analyses determine that though the cores in the sample assemblage could have been from the same population as those from 45CA426, the microblades and microblade fragments from the respective sites could not be from the same population. In comparison to metric data provided by Walker (1999) of length, width, and thickness measurements of microblade artifacts of unspecified material types at regional sites, the artifacts in the sample assemblage appear to be quite similar, but were not statistically analyzed (Table 12).

Table 11. Metric comparisons between microblades of the sample assemblage and those from 45CA426 (Walker 1999).

Measurement	Author	Range	Mean	Median	S.D.	Sample Size
Length (mm)	Walker (1999)	8.07-29.09	18.21	18.32	4.19	126
	This Analysis	6.88-25.23	13.97	13.33	4.58	28
Width (mm)	Walker (1999)	2.16-9.35	5.37	5.49	1.13	367
	This Analysis	1.81-8.0	5.00	4.96	1.28	46
Thickness (mm)	Walker (1999)	0.17-2.74	1.34	1.32	0.36	367
	This Analysis	0.66-5.36	1.66	1.42	0.88	46

Table 12. Microblade measurement (mm) comparisons between sites in the region (additions to Walker 1999).

Site	Mean Length (sample size)	Mean Width (sample size)	Mean Thickness (sample size)	Reference
Hoko River (45CA213)	14.4 (22)	5.29 (24)	1.23 (24)	Croes 1995
Georgeson Bay (DfRu 24)	-	4.85 (30)	1.42 (30)	Haggarty and Sendey 1976
Shoemaker Bay (DhSe 2)	19.1 (28)	6.2 (91)	1.8 (91)	McMillan and St. Claire 1982
Bowker Creek (DcRt 13)	14.02 (13)	5.10 (60)	1.19 (60)	Mitchell 1979
Willows Beach (DcRt 10)	21.4 (7)	6.3 (63)	1.27 (63)	Kenny 1974
45CA426	18.21 (126)	5.37 (367)	1.34 (367)	Walker 1999
45SK46, 45WH51, 45WH17,45WH47, 45WH55, 45WH59	13.97 (28)	5.09 (46)	1.668 (46)	

Presence of Cortex

Cortex (unweathered natural crystal face) was recorded on at least one surface on over half of the artifacts in the sample assemblage (Figure 16). All 8 had cortex, and of these cores, 3 had cortex on more than their just dorsal surface, while the other 5 had cortex present only on their dorsal surfaces. Walker (1999) labels some microblades from 45CA426 as “primary” blades, meaning that their dorsal surfaces are completely covered in cortex. She suggests that this artifact type serve the purpose of cortex removal flakes. No primary blades are present in the sample. Cortex is recorded more frequently on flakes than it is not, while it is less commonly recorded on microblades and shatter (Table 13). This suggests that shatter may be associated with a later stage of reduction as cortex would no longer be present on the microblade core.

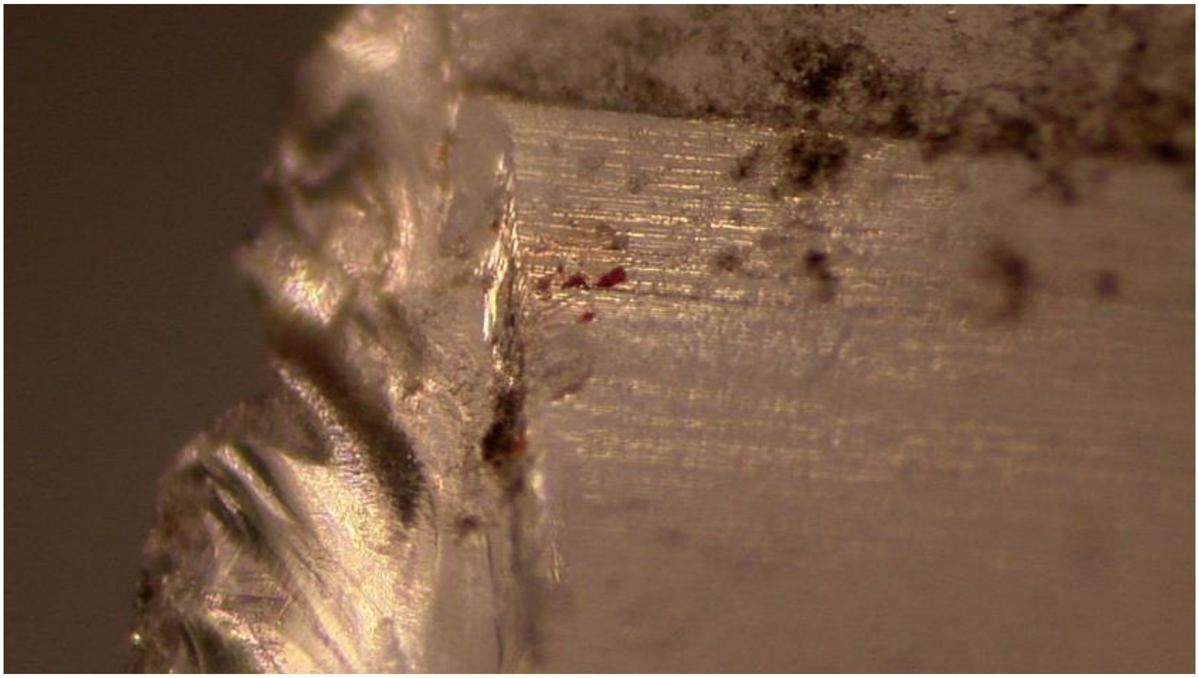


Figure 16. Horizontal striations characteristic of cortex (45WH55- Artifact #760).

Table 13. Presence (P) and absence (A) of cortex by artifact type and site.

	Microblades		**Flakes**		**Shatter**		**Core**		**Artifact Total**
Site	**P**	**A**	**P**	**A**	**P**	**A**	**P**	**A**	
45SK46	2	6	0	1	0	2	0	0	**11**
45WH01	0	3	0	0	0	0	1	0	**4**
45WH17	0	0	0	0	0	0	1	0	**1**
45WH47	0	0	0	0	0	0	1	0	**1**
45WH55	2	5	1	0	1	1	0	0	**10**
45WH59	7	21	4	2	1	1	5	0	**41**
Totals	**11**	**35**	**5**	**3**	**2**	**4**	**8**	**0**	**68**

Cross Section

At 45CA426 trapezoidal cross sections were most common at 84%, followed by triangular at 10%. Microblades with more than 2 arises, a category not present in the sample assemblage, make up 6%. The cross section observations for the sample assemblage are similar (Table 14). Of the 46 microblades, the most common cross section shape observed was trapezoidal. At each site, trapezoidal cross sections were also the most common, followed by triangular and then lenticular. Note that 45WH17 and 45WH46 are not present in the table, as they did not contribute any microblades to the sample assemblage.

Table 14. Microblade cross section shapes observed at each site.

Site	Lenticular	Trapezoidal	Triangular	Total
45SK46	1	6	1	8
45WH01	0	2	1	3
45WH55	1	4	2	7
45WH59	2	20	6	28
Total	4	32	10	46
Percentage	**8.70%**	**69.57%**	**21.74%**	**100%**

Cross section can suggest the stage of manufacture within microblade core reduction. A triangular cross section indicates an earlier stage of manufacture because the single dorsal arris would likely be made from the meeting of two natural crystal faces. A trapezoidal cross section is indicative of a blade made in a secondary stage of manufacture as the presence of an additional dorsal arris is likely caused by the negative flake scar of previously removed microblades (Banning 2000). Multiple cross section types within each site’s assemblage suggests that a single core might have been reduced through several stages at the site, or that cores at different stages of reduction were brought to the site. No refits between blades and cores were present in the sample assemblage. Varying stages of manufacture are present within the sample assemblage as natural crystal ridges and cortex are present on some tools, while negative flake scars are exhibited along the dorsal surfaces of others.

Cortex and Cross Section

Frequencies of cortex were similar on microblades with trapezoidal and triangular cross sections (22 and 20% respectively) while both of the lenticular cross sections were associated with cortex (Table 15). I was surprised by these results as I assumed triangular cross-sectioned microblades would be most likely to exhibit cortex because the platform directly above the ridges formed by natural crystal faces is inherently a good place to remove microblades. This juncture is discussed as a place to removal blades from by Walker (1999), and is where I was able to most successfully remove microblades during production experiments. Results may be due to the small sample sizes as only 4 lenticular and 10 triangular cross sectioned microblades were included in the assemblage. The lack of cortex present on microblades with trapezoidal cross sections suggests that these artifacts were produced in a later stage of reduction. A flake, likely another blade, would have removed cortex and formed a negative flake scar or the dorsal surface of the microblade, making the trapezoidal cross section shape.

Table 15. Cortex in Relation to Cross Section

Cross Section	Cortex Present	Cortex Absent	Total
Lenticular	2	2	4
Trapezoidal	7	25	32
Triangular	2	8	10
Total	11	35	46

Termination Type

Termination type was recorded for 27 of the 28 complete blades (Table 16). One microblade (45SK46 #407) had a rounded distal tip (Figure 17), which did not allow for the identification of termination type, so it was not included in this portion of the analysis. No distal microblade fragments were present in the sample assemblage. In the set of 27 complete microblades, feather terminations are most abundant (51.85%), followed closely by step termination (29.63%), and then hinge termination (18.52%).

Table 16. Termination types, counts, and percentages for the complete blades in the sample assemblage.

Termination	Count	Percentage
Feather	14	51.85%
Step	8	29.63%
Hinge	5	18.52%
Total	27	100.00%

Figure 17. Artifact #407 from site 45SK46 with rounded distal tip and wear along left lateral edge.

Microwear Analysis of Complete Blades

Raw microwear data for the complete blade analysis can be found in Appendix H. The most commonly used part of the microblades was the distal most section on the left lateral edge (L3); 21 of the 28 complete microblades (75%) exhibited microwear patterns on L3 (Figure 18). Blade portions L1 and L2 were almost as frequently used, with microwwear recorded 19 times for each portion (67.9%). The right lateral edges of these tools showed microwear at lower frequencies; 15 of the 28 complete blades exhibited microwear on R3 (53.6%), while microwear was recorded for R1 and R2 portions 12 times (42.9%). Many of the microblades had microwear on both lateral edges, but microwear on either lateral edge differed in scar patterns. This difference suggests that the blades may have been used as a side-hafted tool that was rotated.

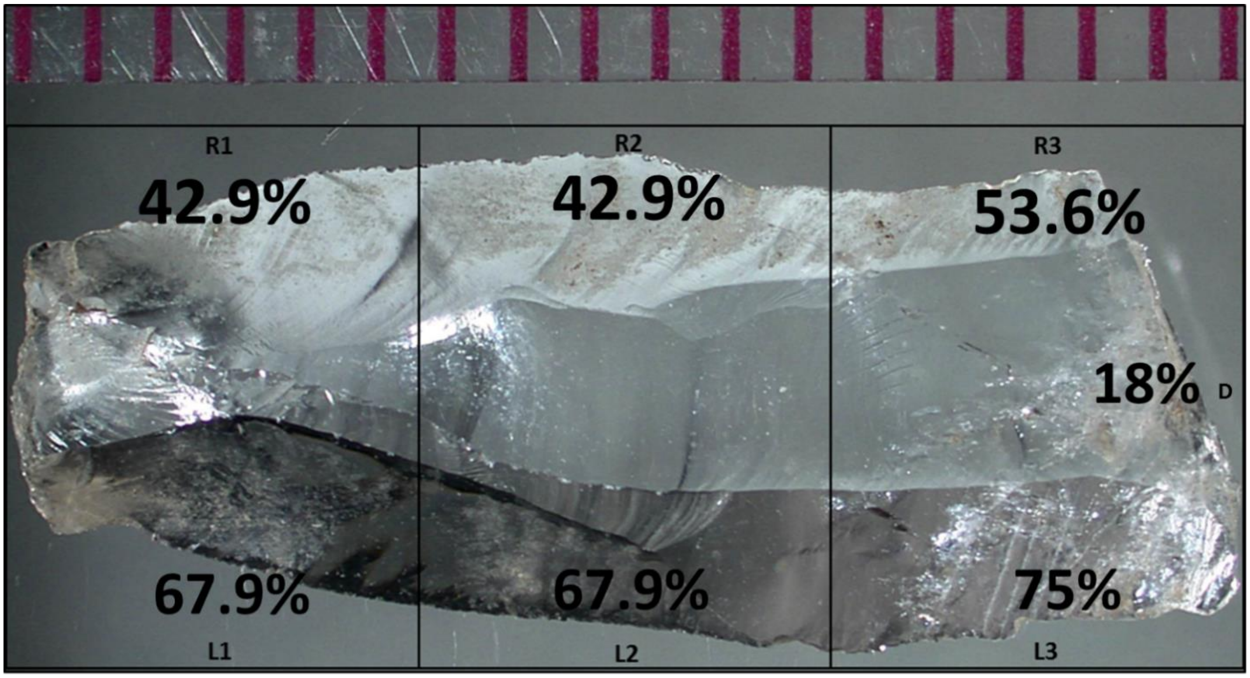


Figure 18. Percentage of microwear on complete blades by blade edge portion.

The distal tip portion (D) exhibited microwear patterns less frequently than one might expect based on previous literature suggesting end hafting. Of the 28 complete blades in the sample assemblage, only 5 (18%) had distal microwear. Walker did not specifically discuss wear on the distal tip of artifacts from the 45CA426, but rather based her assessment of end-hafting on the fact that scar patterns were found closer to the distal ends than the proximal ends of the microblades in her analysis. This analysis has comparable results in that the frequency of wear on R3 and L3 is higher than on the more proximal margins, but Walker does not provide comparable information on the portion that I am calling D. The lateral microwear observed on the sample assemblage matches the expectations for side-hafted tools, while the presence of distal microwear matches that for end-hafted tools. Therefore, the microwear patterns observed in the sample assemblage suggest these microblades were both side and end hafted, but that they were much more commonly side hafted. Further, the sample demonstrates that side-hafting practices were occurring on quartz crystal microblades during the Locarno Beach Phase, as Flenniken (1981) suggested likely occurred at the Hoko River site.

Scar Orientation on Blade Edge

Scar orientation along blade edges varied, with some edges exhibiting only perpendicular or oblique scars, while others had a combination of scar orientations along a single part of the blade edge. Some of these overlapped or had organized repetitive patterns. All blade sections that displayed both perpendicular and oblique scar orientation, regardless of the pattern were lumped together into a combined category. Of the 103 blade portions that exhibited microwear patterns, 82 of those patterns were exclusively perpendicular to the blade edge (79.6%), 16 were a combination of perpendicular and oblique scars (15.5 %), and only 5 were scars oriented exclusively at an oblique angle to the blade edge (4.9%).

Scar Types Observed

Five of the 28 complete blades exhibited only a single type of scar pattern on their blade edges (Table 17). The other 23 microblades had multiple scarring patterns on lateral and distal blade portions.

Table 17. Complete microblades exhibiting only a single type of scarring pattern on any/all edges.

Site	Artifact #	Scar Type	# of Blade Portions
45SK46	1172	HM	1
45WH59	46	SC	3
45SK46	1165	SCHM	2
45WH59	59	SCHM	4
45WH59	67	SCHM	2

Key: Scalar (SC), Halfmoon (HM), SCHM (Combination of Scalar and Halfmoon Scars)

Of the 103 portions with scars in the complete blade assemblage, 66 (64%) were made up of multiple different scar types, while the other 37 (36%) of the assemblage showed exclusively SC (scalar), ST (step), or HM (half-moon) scars (Figure 19, Table 18). The most common observed scar type was SC, recorded 29 times (28.2%), followed closely by SCHM at 26 (25.2%). Some combinations of scars were only recorded once. In total, these combinations make up for 13.59% (n=14) of the scar types observed and were the result of multiple scarring patterns within a single blade portion. For example, SC/SC/SCHM represents a scalar pattern, followed by a different scalar pattern, followed by a pattern of repetitive scalar and half-moon scars. Of these individual combinations, the most common scar type was once again SC, followed by SCHM (Table 19).

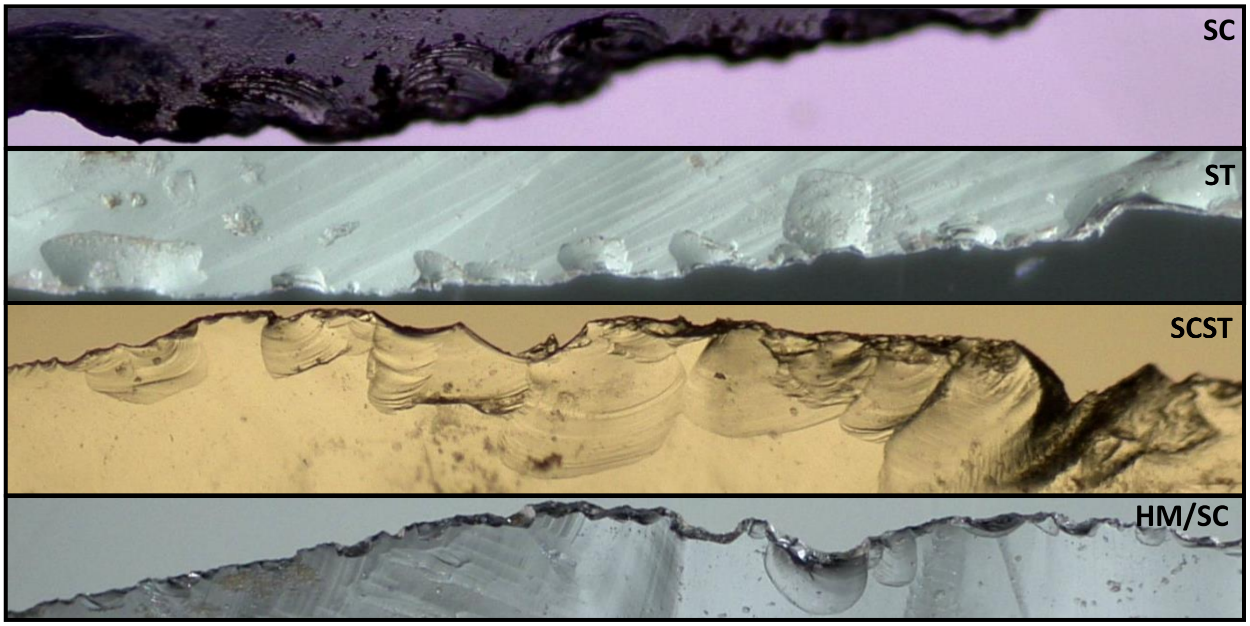


Figure 19. Examples of differing microwear patterns along artifact edges.

Table 18. Types of scar patterns recorded on portions of complete microblades.

Scar Type	# of Times Observed	% of Sample
SC	29	28.16%
SCHM	26	25.24%
HM	7	6.80%
SCST	7	6.80%
HM/SC	4	3.88%
HM/SCHM	3	2.91%
SC/SC	3	2.91%
SC/SCHM	3	2.91%
SCHMST	3	2.91%
SC/SCHM	2	1.94%
SC/SCST	2	1.94%
Other Combos	14	13.59%
Total	103	100%

Table 19. Scar types within combination patterned portions.

Scar Type	# of Times Observed	% of Sample
SC	10	33.33%
SCHM	6	20.00%
HM	4	13.33%
SCHMST	4	13.33%
HMST	2	6.67%
SCST	2	6.67%
ST	2	6.67%
Total	30	100%

A continuous pattern along an entire lateral edge suggests that it was exposed to the same use. Of the 28 complete blades, 6 had lateral edges with the majority of all three blade portions covered with the same continuous scar pattern. Artifact #15 from 45WH59, two of these portions were found on opposite lateral edges (Figure 21). Three complete blades had a continuous scar pattern covering the majority of two portions. Though portion separations are arbitrary, this means that at least half the edge was a continuous scar pattern. Four complete blades had matching scar patterns on opposite lateral portions. Artifact #1591 from 45WH55 had a continuous SCHM scar pattern on R3, D, and L3 (Figure 20). This suggests that #1591 may have been end hafted with these three edges being exposed to the same use.

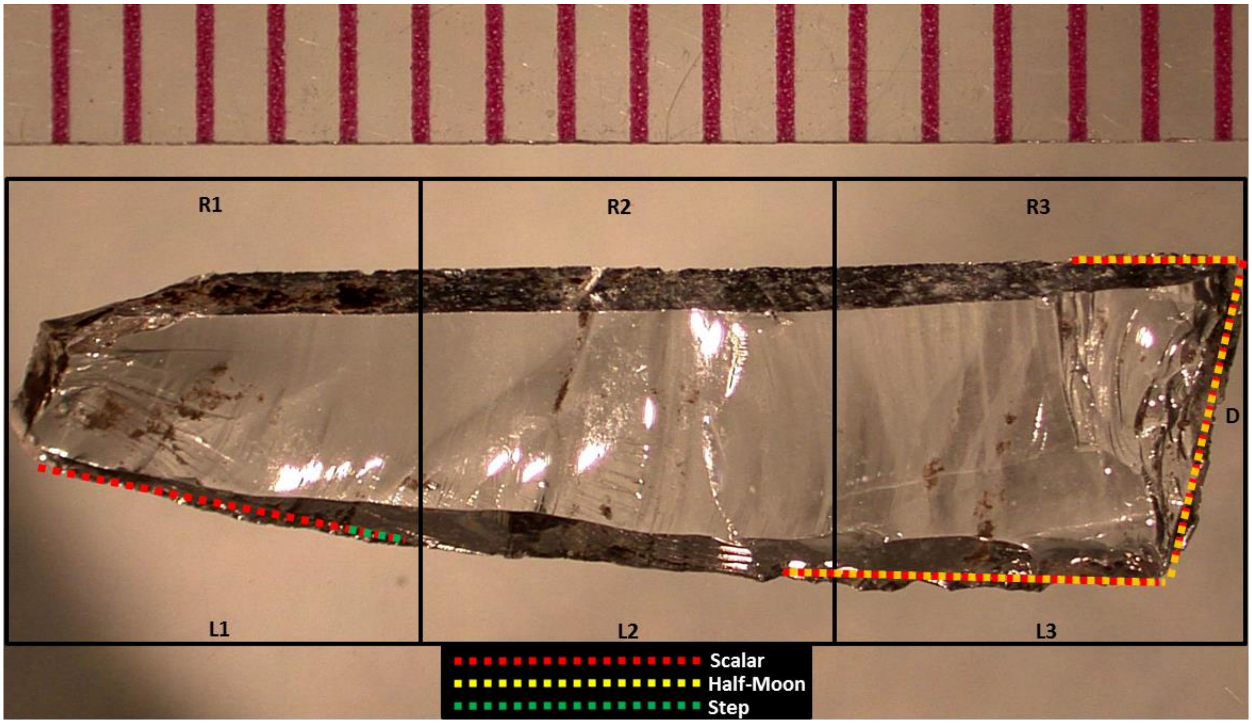


Figure 20. Artifact #1591 from 45WH55 with a SCHM scar pattern covering its distalmost portion.

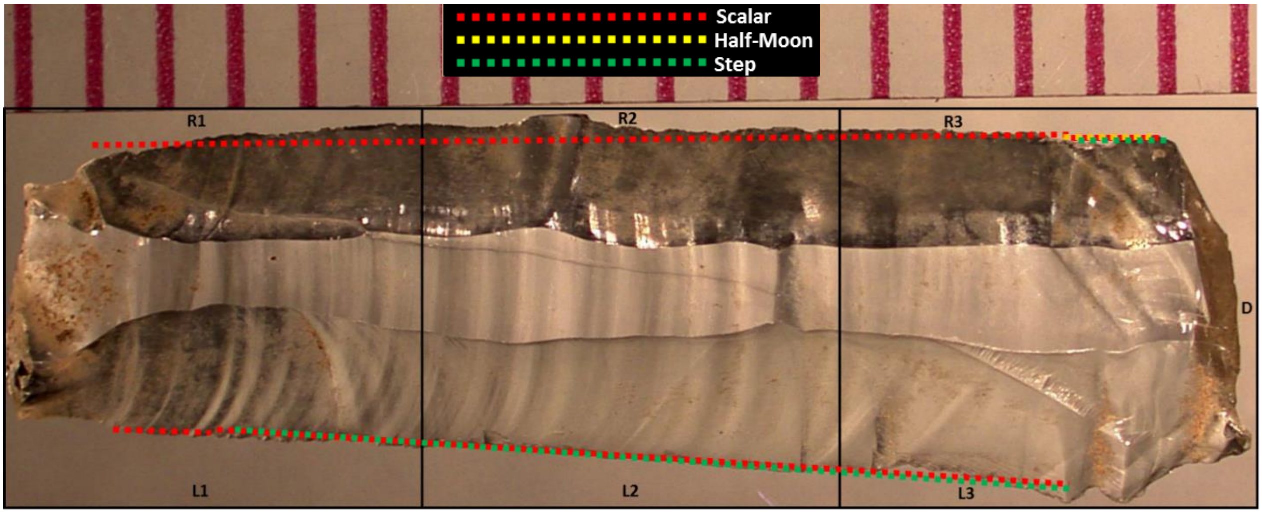


Figure 21. Artifact #15 from 45WH59 with different microwear patterns covering almost the entirety of both lateral edges.

I did not observe polish as a type of wear, likely because the levels of magnification utilized for microwear analysis in this research were not high enough to identify polishes. According to Igreja (2009) polish is not easily visible on quartz crystal artifacts and she only saw them under high levels of magnification. Rounding of tool edges that one would generally equate to polish was noticed occasionally, such as seen in Figure 17 on the distal tip of Artifact #407 from 45SK46.

Residue Analysis

Morphological and microwear analyses helped determine which tools should be analyzed using residue analysis. Residues visible to the naked eye or with limited magnification were noted on the Attribute Analysis Form and then viewed at greater magnification levels. I observed colored residues on 58 of the 68 artifacts in the sample assemblage. Residue color was highly variable, ranging from dark black spots to light brown resin-like coverings, and red scaly smears to thicker coverings with attached particles (Figure 22).

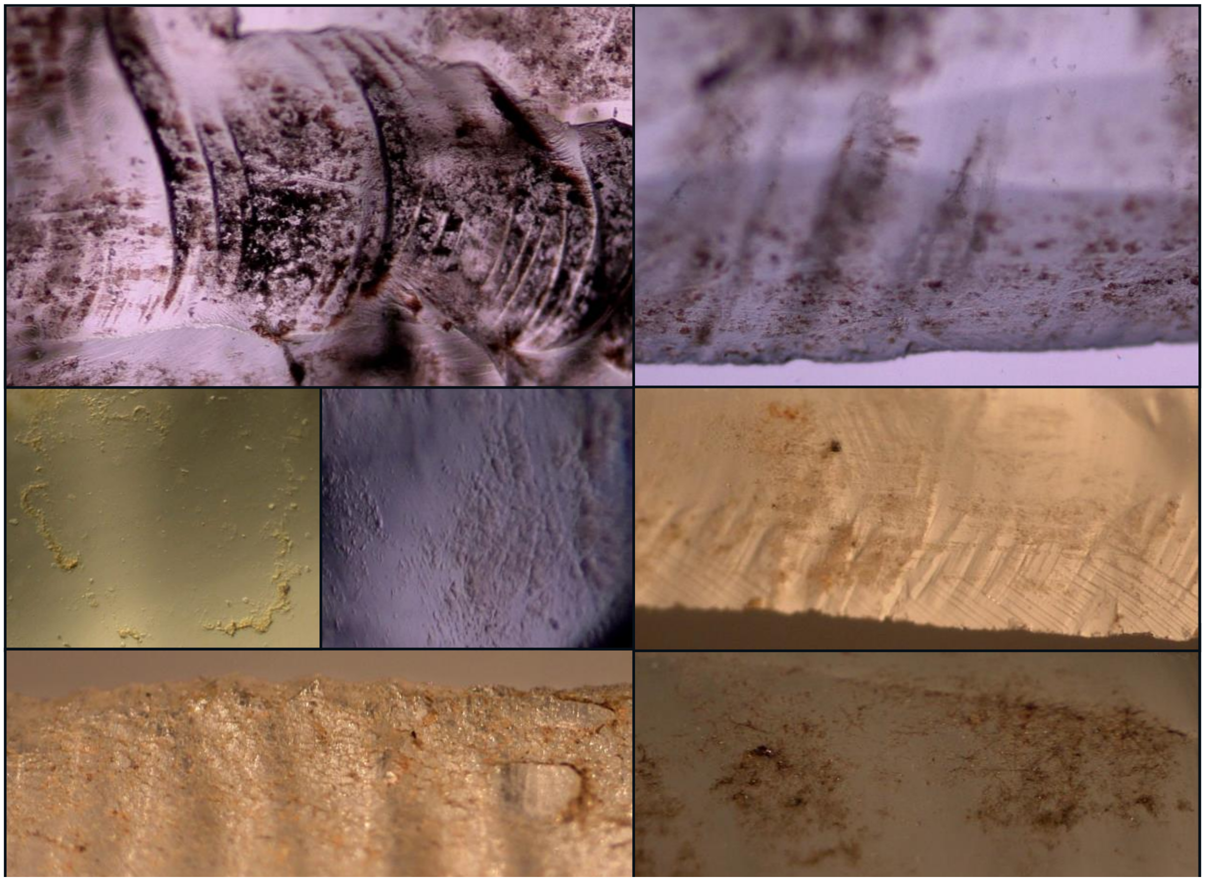


Figure 22. Examples of residues observed on microblade surfaces.

Two techniques were used for residue analysis on the sample assemblage. Inorganic compounds were identified using a scanning electron microscope equipped with an energy-dispersive x-ray spectrometer (SEM-EDX). Organic residues were identified using the cross-over immuno-electrophoresis (CIEP) technique. I tested a subsample of the sample assemblage using each of these analysis (EDX: n=19, CIEP: n=25).

Colors of Residues Observed

Residues were found on 58 of the 68 objects analyzed. A total of 86 residues, falling within 11 general color categories were recorded (Figure 23). The most commonly observed color of residue was dark brown, but other shades of brown, black, white, red, and green were also recorded on the objects. A small number of the artifacts (n=10) had no visible residues on their surfaces.

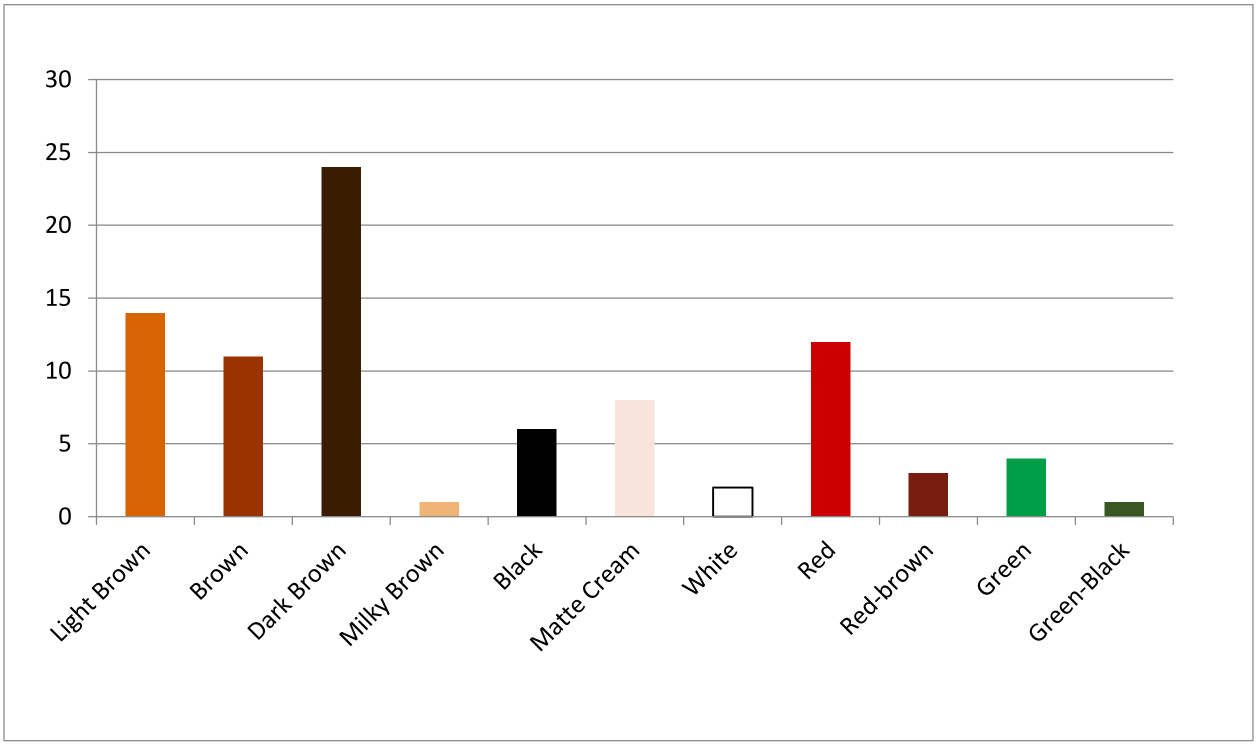


Figure 23. Colors of residues observed on artifact surfaces (n=86).

Compositional Analysis of Residues using Energy-Dispersive X-ray Spectroscopy

Residues on the surfaces of 23 of the artifacts in the sample assemblage were tested using SEM-EDX. During this analysis, I also tested the bare surface of each artifact for comparison and material verification. Of the 23 artifacts analyzed, all were confirmed to be quartz crystal (SiO_2). Carbon, aluminum, feldspar, calcium, sodium, phosphorous, iron and magnesium were commonly recorded on the subsample assemblage. These elements are commonly found in soils, so their presence may be natural (Schaetzl 2005). Alternatively they could be due directly to human behavior. Phosphorus is found in animal bones and it is natural to find this mineral in archaeological sites (Holliday 2007). Other combinations of elements such as calcium carbonate (found in shell) and sodium chloride (salt) could be suggestive of prehistoric behaviors. Sodium chloride for example, could be from human sweat during handling, and may have occurred prehistorically, or during excavation and curation.

Elements that stood out as unusual during SEM-EDX analysis were cobalt (Co) and molybdenum (Mo), which are used in pigments. Spectra displaying these results can be found in Appendix I. Cobalt was identified on artifact #176, a core from 45WH59 (Figure 24) and molybdenum on artifact #760 from 45WH55. The elevated level of iron on artifacts #760 from 45WH55, and #27 and #40 from 45WH59 was abnormal. The combination of iron and oxygen on these tools, along with the red coloring of residues on artifact surfaces is indicative of the presence of hematite, also known as red ochre (Fe_2O_3).

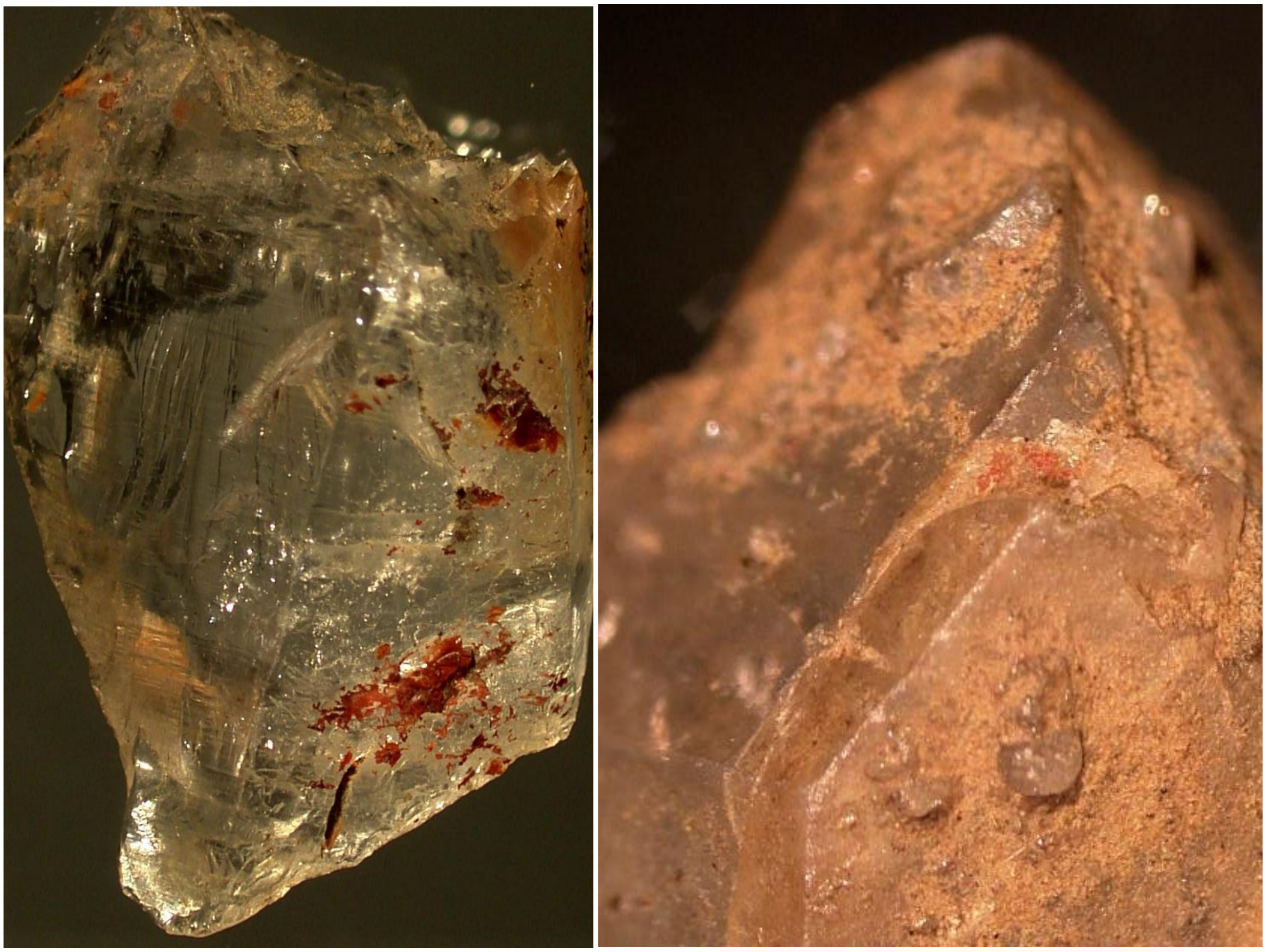


Figure 24. Artifacts with pigment residues and elevated iron levels from site 45WH59: Artifact #176 (left) and Artifact #40 (left).

Red ochre is commonly associated with ritual practices (MacDonald 2008; Wreschner et al. 1980). The connections between Coast Salish peoples, quartz crystal, red ochre, and ceremonial activities described by Hickok et al. (2010) suggested that I pay special attention to the quartz crystal artifacts in this assemblage with red ochre residues on their surfaces. Ochre residues were photographed using the SEM and viewed at other magnification levels using the stereomicroscope and dissecting microscope. This residue has a diagnostic platy texture and vibrant red color (Figure 25). Due to the difficulties and time constraints associated with SEM-

EDX and the quartz crystal material type, red ochre was recorded and compositionally analyzed on only a sample of artifact surfaces using this technology. Based on visual identification rather than EDX, I believe an additional four artifacts: a core (45WH59-#27), a medial microblade fragment (45WH59-#9), and two proximal microblade fragment (45WK46-#402 and 45WH59-#31), have red ochre residues on their surfaces.

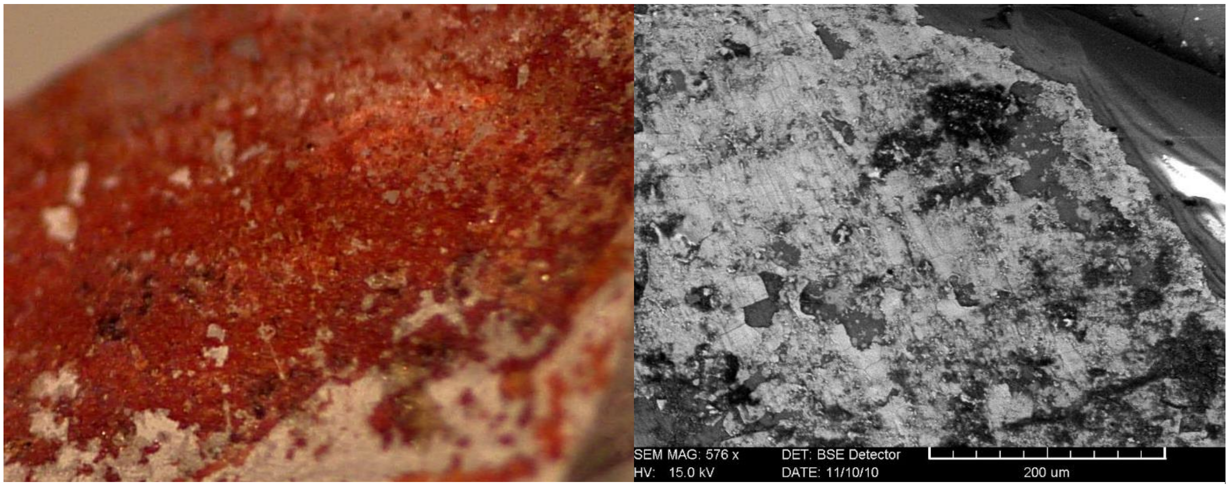


Figure 25. Platy texture of red ochre residue on Artifact #760 from site 45WH55. Stereomicroscope (left) and SEM (right).

A split core from 45WH49 (Artifact #27) is an interesting example of red ochre application. Half of this core is covered completely with cortex, with multiple areas of showing red ochre residues (Figure 26). These residues occur on only the cortical surface of this quartz crystal core, suggesting a purposeful application of ochre to the entire core prior to the crystal being split.

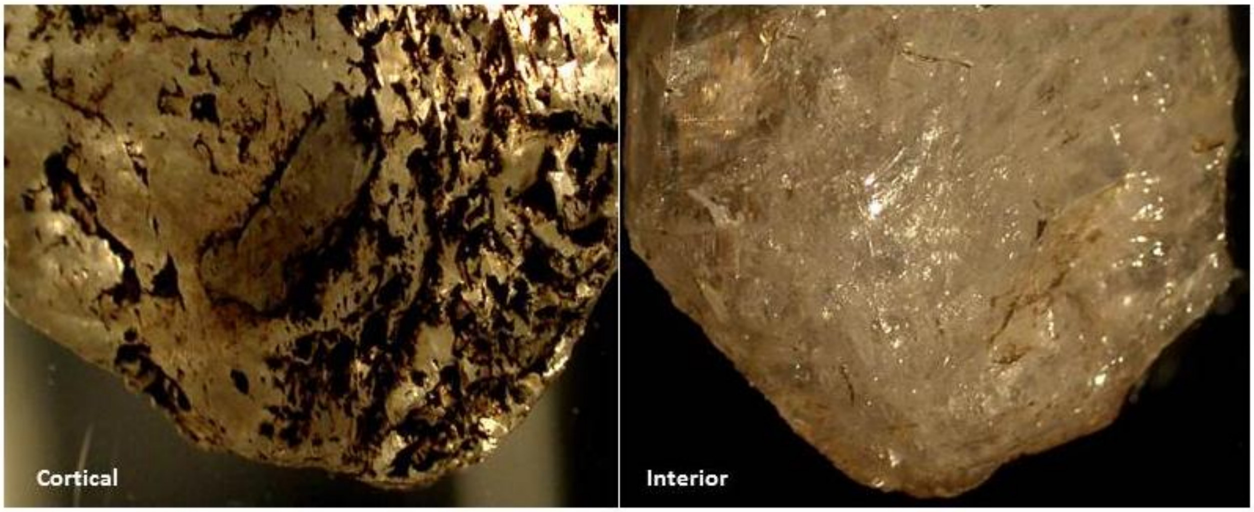


Figure 26. Artifact #27 from site 45WH59, with residues including red ochre covering only the cortical surface.

A complete microblade (Artifact #760) from site 45WH55 has a visible red residue on its sharp, angled distal tip ending proximally in a straight line perpendicular to the blade length (Figure 27). The position and distinct separation between the residue and the rest of the microblade suggests hafting material may have been present at the time the ochre was adhered to the blade. Campbell et al. (2010:55) suggests that “the residue adhered to the tip when it was fastened into a haft and that the residue accumulated above the haft or binding." When analyzed using SEM-EDX, the residue was confirmed to be red ochre. The occurrence of this material on a quartz crystal microblade suggests that this tool was used at an event of some level of religious importance and results from this analysis motivated me to perform further tests on the artifact using CIEP protein residue analysis.

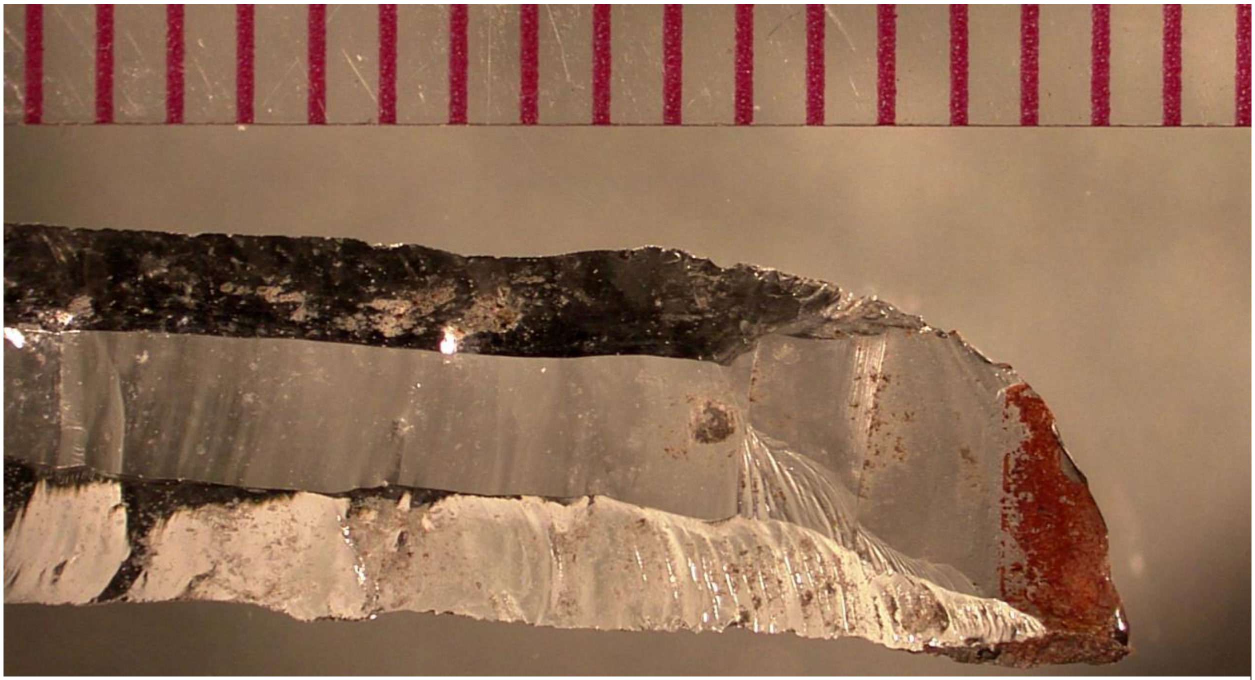


Figure 27. Artifact #760 from 45WH55 with ochre covered distal tip.

Cross-over Immuno-electrophoresis (CIEP) Protein Residue Analysis

Two separate sample sets tested using CIEP analysis allowed for 25 artifacts from the assemblage to be analyzed against antiserums of 16 animal/fish and 5 plant taxa. These antiserums were materials that may have been found in the Salish Sea region during the Locarno Beach Phase (Table 20). Six tools from three sites yielded seven positive results for four taxa: deer, human, salmon, and rabbit (Table 21). The first sample of 15 artifacts was hand-delivered to CSUBLAS, and I assisted with or viewed all stages of the analysis in November 2013. Three positive reactions resulted. The second sample of 10 artifacts was tested by the CSUBLAS in April 2014, resulting in 4 positive reactions. The complete CIEP report by CSUBLAS is located in Appendix J.

Table 20. Antiserum types and possible species identified during CIEP analysis (from CLUBLAS 2014).

Antiserum to:	**Reacts with:**
Alligator	alligator, crocodile
Bear	black, grizzly, etc
Bovine	bison, cow, musk ox
Camel	all camelids (New & Old world)
Cat	bobcat, cougar, lynx, etc.
Chicken	quail, grouse, & other gallinaceous fowl
Deer	deer, elk, moose
Elephantidae	elephant, mammoth
Guinea-pig	beaver, guinea-pig, porcupine, squirrel
Horse	horse, donkey, kiang, etc.
Human	human
Rabbit	rabbit, hare, pika
Rat	all rat & mouse species
Sheep	bighorn & other sheep
Triops	triops (crustacean)
Trout	trout and salmon species
Agave	yucca, agave
Amaranthaceae	amaranth, pigweed, *quelite*, etc.
Asteraceae	rabbitbrush, sagebrush, sunflower, thistle
Camas	camas, wild hyacinth
Capparaceae	beeplant, bladderpod, stinkweed, etc.
Chenopodiaceae	goosefoot, greasewood, pickleweed, saltbush, etc
Cupressaceae	cedar, cypress, juniper
Lessoniaceae	kelp, possibly algae
Lomatium	*Lomatium sp.*
Malvaceae	mallows
Mesquite	mesquite, palo verde, other legumes
Portulacaceae	bitterroot
Pinaceae	fir, hemlock, pine, spruce

Table 21. Results of CIEP analysis of samples of 25 quartz crystal artifacts sent to CSUBLAS (CSUBLAS 2014:5).

Site #	Artifact #	Description	Results
*45SK46	407	Microblade	**Salmon**
45SK46	1163	Microblade	Negative
*45SK46	1164	Microblade	Negative
*45SK46	1165	Microblade	Negative
45SK46	1166	Microblade	Negative
*45SK46	1168	Microblade	Negative
*45SK46	1171	Flake	**Deer, Human**
*45SK46	1172	Microblade	Negative
*45WH1	54	Microblade	**Human**
45WH1	119	Microblade Fragment (Proximal)	**Rabbit**
45WH1	179	Microblade	Negative
*45WH17	1344	Microblade	Negative
*45WH55	507	Shatter	Negative
*45WH55	612	Flake	Negative
45WH55	707	Microblade	Negative
45WH55	760a	Distal Tip of Blade	**Human**
45WH55	760b	Remainder of blade	**Human**
45WH55	1147	Microblade Fragment (Medial)	Negative
45WH55	1565	Microblade (Proximal)	Negative
45WH55	1817	Microblade	Negative
45WH59	9	Microblade Fragment (Medial)	Negative
45WH59	15	Microblade	Negative
45WH59	16	Microblade	Negative
45WH59	31	Microblade Fragment (Proximal)	Negative
45WH59	36	Microblade Fragment (Proximal)	Negative
45WH59	37	Microblade	Negative

*Indicates the second set of samples tested.

Artifact #760 from 45WH55 resulted in two positives for human, from its ochre-covered tip and also from the remainder of the blade, with a stronger positive reaction on the tip. Soil from the corresponding layer collected in level bags during excavation was tested in order to verify that the proteins were directly from the artifact, and not the surrounding soil. Results for human protein in the soil were negative. The presence of human protein on artifact #760 and specifically its higher concentration on the ochre coated distal edge supports that this tool could have been used for a ceremonial event, possibly involving the piercing of human skin. It would be easy to imagine a microblade being used in a lip cutting ceremony for a labret insertion (lower lip piercing) or ear piercing for placement of ear spools, as both of these types of adornments were used as symbols of social status during the Locarno Beach Phase (Ames and Maschner 1999; Carlson 1996; Matson and Coupland 1995; Mitchell 1990).

The argument for ritual use is not as strong for the other blade, Artifact #54 from 45WH01 that tested positive exclusively for human protein because there is no associated ochre. Results for human protein in soil from the corresponding stratigraphic layer were negative. Human proteins could be left on the blade due to an accident while handling. The combination of human and deer proteins on Artifact #1171 from 45SK46 is suggestive of an accidental injury during a meat processing event.

Artifact #119 from 45WH1 tested positive for rabbit. Soil from the strata in which this tool was excavated was not collected, so it could not be tested. Leporidae (rabbit, hare) remains were not observed by Dubeau (2012) in his mammalian faunal analysis of 45WH1.

Artifact #407 from 45SK46 tested positive for salmon and artifact #1171 from the same site resulted in a positive reaction to deer (and human). Residues from multiple taxa within the same site, as well as at different sites within the sample assemblage strongly supports the hypothesis that quartz crystal microblades were multiuse tools.

Six of the 25 tested artifacts from the sample assemblage resulted in positive protein identifications. Lack of positive results on the other artifacts can not be taken as an indicator that they were not used to process plant and animal tissues. A number of factors may have affected preservation and identification of proteins. These artifacts could potentially have had residues of plants or animals not included within the antiserum available to test against. Also, organic residues could have been absent or degraded due to post-depositional processes. The best candidates for CIEP protein residue analysis are tools found in dry climates with limited acidity in the soil (pH above 4). Preservation of proteins is less common in climates with higher moisture levels, such as tropical and rainforest environments. The acidity of the soil in the Salish Sea region generally has a negative impact on the preservation of residues (R. Yohe, personal communication, October 10, 2013). Shell deposition can lead to a more alkaline environment in this region, however. This is likely the reason that residues were preserved at 45SK46, 45WH1, and 45WH55 but not at 45WH59, the only non-shell bearing site.

Artifact Cleaning

Researcher's opinions differ on the necessity and impact of cleaning tools before analysis (Andrefsky 2005; Keeley 1980; Odell 2004). Site records include no evidence of previous washing of any of the artifacts within the sample assemblage. The intent to do protein residue analysis led me to not wash any artifacts, as I did not know at the beginning of the analysis which artifacts would be chosen for the procedure, and did not want to remove any potential residues. I believe the choice to not clean artifacts in the sample assemblage did not affect the results of the microwear analysis. The lighting and microscopic tools used for analysis, along with the natural clarity of the quartz crystal material and limited amounts of attached sediment allowed scarring patterns and residues to be quite visible through all stages of the analysis.

A sample of artifacts were washed during the cross-over immuno-electrophoresis protein residue analysis at California State, Bakersfield's Laboratory of Archaeological Science (CSULAS). I viewed these objects microscopically before and after the analysis and found that the gentle agitation that occurred within solutions during the testing procedure removed only a limited amount of the residues on the surfaces and edges of artifacts (Figure 29 and Figure 28). This indicates that the CIEP process does not negatively impact additional analysis methods. Additionally, Dr. Yohe said they would still be eligible for future residue analyses.

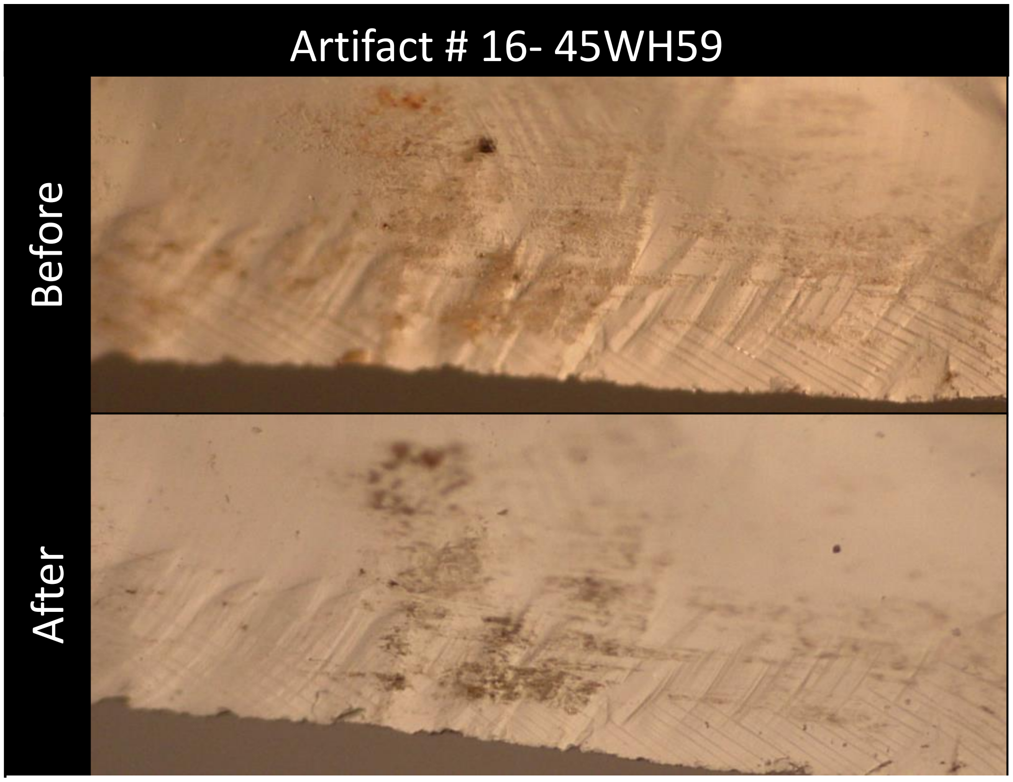


Figure 29. Artifact #16 from 45WH59 before and after CIEP analysis.

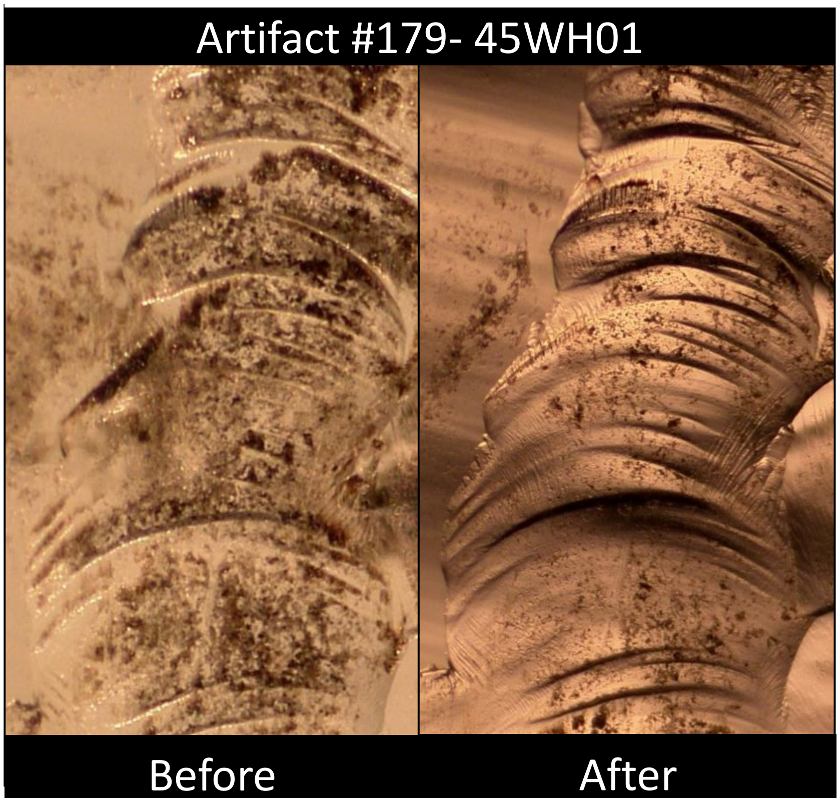


Figure 28. Artifact #179 from 45WH01 before and after CIEP analysis.

Production Discussion

The morphological analysis shows that the sample assemblage was produced using methods previously described in the literature. Relatively pristine prismatic quartz crystals were modified at one end to create striking platforms and microblades were removed by striking above natural ridges and moving around the circumference of the core, producing a few lenticular flakes, triangular blades and then trapezoidal blades. Although trapezoidal blades are the most frequent, blade removal did not necessarily penetrate far towards the center of the core, because cortex occurred in approximately a fifth of these. The recovered cores were not all exhausted, some were still of sufficient size to remove microblades similar in size to others in the assemblage. The knappers were relatively successful in removing microblades that ran the entire length of the crystal, as indicated by their overall length compared to the core length and in a few cases by a crystal face on the distal end.

My observations do not suggest that blades were removed from both ends of the crystal which Reher and Frison (1991) suggest is possible. Based on observations of the sample assemblage, I believe the manufacture of quartz crystal microblades was likely unidirectional. This is supported by microblades with angled natural crystal faces as part of their distal ends (Figure 30). A core was likely struck at a prepared platform at the growth base of the crystal. This end of a crystal is often slightly wider, and only limited grinding would allow a flat surface to be produced. Successful blade removal in this manner was produced during quartz crystal microblade manufacture experiments. Microblades in the sample assemblage that exhibit natural crystal faces with natural ridges running vertically down the blade could have been produced by striking either end of the core. While this is true, the additional steps necessary to prepare a platform from the crystal tip rather than the growth end of the crystal, along with the potential for an unpredictable fracture when force moves through this uneven portion of the crystal implies that this may have been less likely.

Figure 30. Artifact #37 from 45WH59 with green crystal inclusions.

Another of Reher and Frison's (1991) suggestions, that inclusions were avoided to allow a clean microblade removal, was exemplified in the sample assemblage. Prehistoric flintknappers chose where to strike the core to remove a blade that encompassed the green pocket-like inclusions towards the tip of an artifact #37 from 45WH59, also exemplified in Figure 30. This impurity could have interrupted the fracture of the blade removal, while intersecting it may have risked an incomplete blade or shattered core.

Limited experimental work allowed removal of blades from a quartz crystal microblade core, with similar sizes and attributes to those in the sample assemblage. This method — previously discussed in Chapter 4 — was successful. Given the difficulty in flake production described by Reher and Frison (1991), I was surprised by how easily blade removal occurred. Blades and flakes removed during this experiment were very sharp.

I also learned how quickly one can exhaust the material with a poorly placed strike. Initially, microblades were removed with a single strike. As the core became more exhausted, it became more difficult to remove blades without damaging the core or producing additional flakes and debitage. This experimentally produced debitage varied in size, but was mostly small pieces of shatter. Shatter and failed flakes likely occurred in the production of the sample assemblage as well, but would not be recovered due to their small size. Some of the microblade fragments may have been created in production as blades failed to detach properly, although others may have broken later in connection with use.

CHAPTER 6: DISCUSSION AND CONCLUSIONS

The goal of this thesis was to identify the function of quartz crystal microblades in the Salish Sea region. As hypothesized, these artifacts were multiuse tools. They were hafted in different fashions, used to process a variety of materials, and may have functioned in ceremonial events. Another goal of this research was to provide a framework for the analysis of this particular material as a tool type. The combination approach of morphological, microwear, and organic and inorganic residue analysis allows for a well-rounded functional assessment that could be repeated on larger data sets of quartz crystal artifacts. It could also easily be adjusted to attempt similar functional analyses of other lithic technologies.

Morphological Analysis

Morphological analysis of the sample assemblage found that the most common object type was a microblade, most often complete. These artifacts measured on average 13.97 mm in length, 5.0 mm in width, and 1.66 mm in thickness. When comparing the measurements in the sample assemblage to those from 45CA426, their core sizes were not statistically significantly different, while microblade length, width, and thicknesses were significantly different (i.e. not from the same population). This could indicate different local manufacturing techniques used on similar size cores. On the other hand, because the sample assemblage represents several sites collected with two different screen sizes, while the 45CA426 assemblage is a much larger assemblage recovered with 1/8" mesh, recovery bias might affect the average sizes.

Further experimental production would provide insight into the manufacture of these tools and the placement of artifacts into tool typologies. Larger data sets would allow a greater comparative analysis within a site or set of sites, and could be combined with this and previous analyses. Larger comparative analyses would lead to an even better understanding of the different uses of these tools by their site type, location, size, or date. Additionally, the sourcing of such a pure mineral would be difficult, but detailed testing of impurities might allow connections to a source of quartz crystal, and to help discover potential trade or travel patterns.

Microwear Analysis

This microwear analysis contributed to the investigation of quartz crystal microblade use by determining: (1) most commonly used edges, (2) potential hafting placement, and (3) scarring types/patterns. Microwear was described, viewed, and photographed at minimal magnification. Separation of complete microblades into portions allowed suggestions to be made as to the placement of hafts. Results of this analysis differed from what was observed at the Hoko River site and suggested by Walker (1999). At the Hoko River site, a single end hafted microblade was recorded (Croes 1995) and microblades from 45CA426 were thought to be end hafted based on microwear analysis by Walker (1999). Microwear analysis of the sample selection indicates that Flenniken (1981) was correct in suggesting that quartz crystal tools may also have been side hafted. Microwear analysis of the complete blades in the sample assemblage suggests these tools were more commonly attached in a side hafted manner. The lateral edges of these tools exhibited microwear more frequently, but not exclusively. Some distal portions of complete blades also exhibited microwear, suggesting these tools were hafted in multiple ways. Microwear pattern types varied greatly in terms of the scar patterns and the extent along blade edges. This variety further supports the interpretation of quartz crystal microblades as mulituse tools that were utilized in multiple ways, on numerous material types. Analysis of wear patterns on microblade fragments could be conducted and generally tied to the blade portions used for the complete blades to give additional information about wear frequency by location. Observing wear in relation to the breaks might illuminate whether the fragments were more likely to be the result of breakage during use or during production.

I lacked an experimental basis to connect specific microwear patterns to particular behaviors. There were no major differences between microwear patterns at different sites that might suggest different functional uses. The frequency of scalar and half-moon scar types and their combinations are similar across the sites in the sample assemblage. Step scars were observed only on microblades from sites 45WH55 and 45WH59; this may be attributable to sampling bias, since step scars are far less frequent than scalar and half-moon scars, and these two sites contributed the largest numbers of microblades.

Much of the difficulty of microwear analysis is derived from the lack of comparable research. Few researchers have studied this specific material type. Those that have, utilized high-powered, rather than low-powered techniques. Experimental analysis in a controlled environment analyzing the effect of multiple variables on material types ranging in hardness levels, including methods and durations of use, are necessary to make inferences as to more specific functions of these tools. Detailed explanations of differing microwear patterns at the low-powered microscopic level would be extremely beneficial to analysts. This research demonstrates that differences in microwear can be seen at the low-powered level. A thorough comparative photograph collection of quartz crystal microwear at the low powered level would be extremely helpful to analysts, as it is a magnification level that is easily accessible.

Residue Analysis

Quartz crystal microblades have previously been associated with bark, fish (Croes 1980), and deer/elk residues (Walker 1999). The results of protein residue analysis in this thesis expands the data set of organic residues connected to these tools by adding rabbit to the list as well as providing additional cases of salmon and deer residues.

Most importantly, perhaps, was testing conducted on Artifact #760, the ochre and human protein tipped quartz crystal microblade from 45WH55. This microblade highlights the value of examining inorganic residues adhered to tools as a method for suggesting function. It also emphasizes the importance of combining inorganic and organic residue methods during residue analyses. Both organic and inorganic residues were necessary to demonstrate the association between this tool and a ceremonial activity. The identification of the presence of ochre residues on additional tools, along with the positive results for human proteins on multiple tools tested using CIEP analysis further supports the connection between quartz crystal microblades and ceremonial functions. I suggest that quartz crystal microblades, including the ones examined for this project, may have served a ritualistic purpose for the prehistoric people of the Salish Sea region. Additional inorganic and organic testing is needed to strengthen the connection between microblades and other proteins, minerals, and a combination of the two.

During microscopic analysis, fibers and particles were occasionally noticed along blade edges (Figure 31 and Figure 32). These were difficult to record as they were often present during one analysis and not the next. These fibers may be prehistoric, or the result of post-depositional surface modification, and further analysis is needed for the identification of these materials.

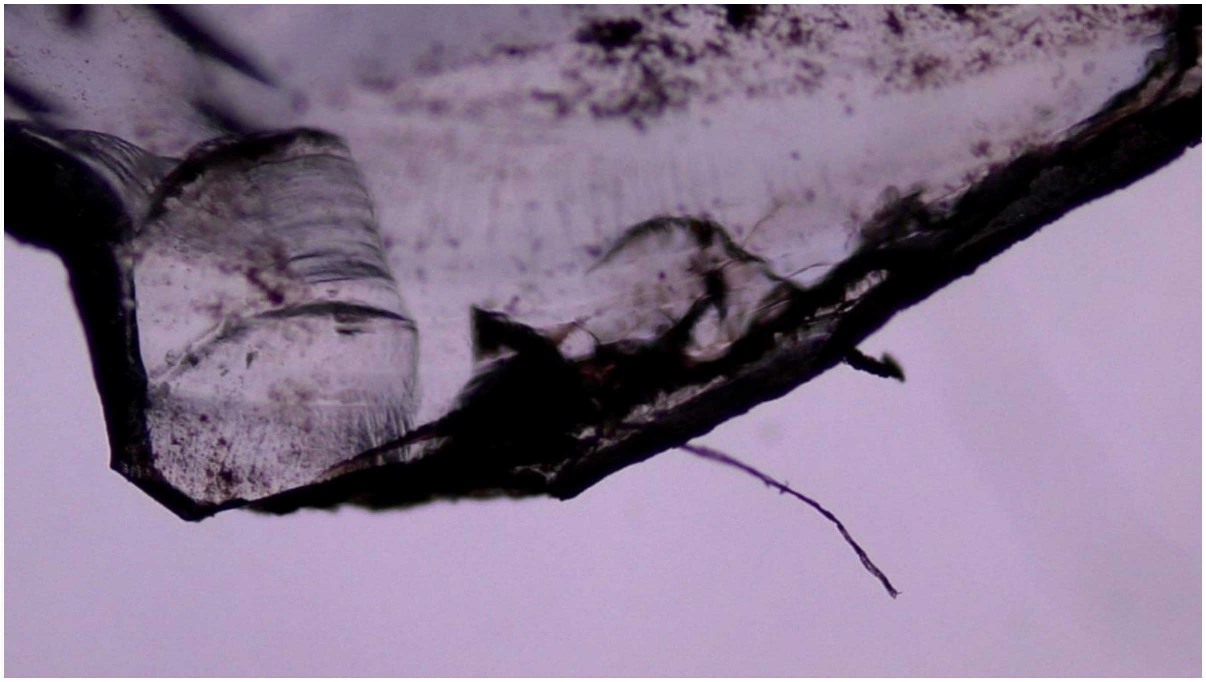


Figure 31. Flake with attached fiber on edge (Artifact #44 from 45WH59).

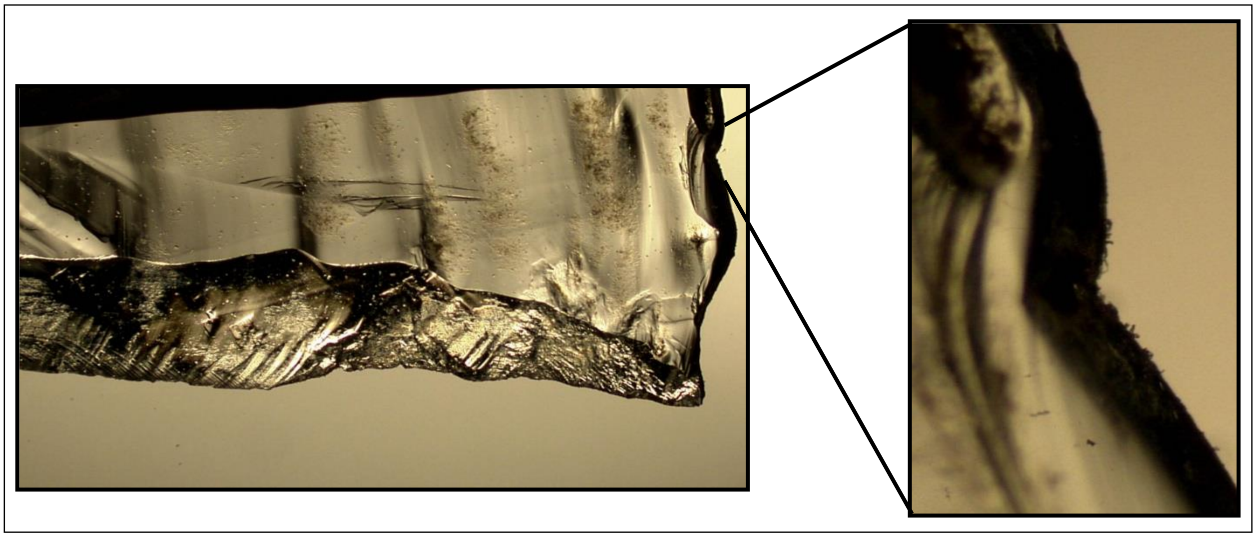


Figure 32. Attached particles to the distal end of a complete microblade (Artifact #16 from 45WH59).

Conclusions

I have used a wide variety of techniques to better understand the function of quartz crystal microblades. Morphological analysis allowed me to characterize the production sequence. I identified the presence of a variety of inorganic residues such as red ochre, cobalt and molybdenum that may be associated with pigments. Organic residues represent several taxa, including salmon, deer, rabbit, and human. Combined with the highly varied microwear types and placement, this data strongly supports the hypothesis that quartz crystal microblades were multiuse tools used for a number of processing activities, and possibly ceremonial events. When combined, morphological, microwear, and residue analysis methods offers a more complete view of these unique prehistoric tools. This integrative approach can be expanded in future research. Experimental production of wear and contextual analyses, especially association with faunal remains, can be used to elucidate the specific nature of processing activities. Potential applications of microblades as fabricators, e.g., for drilling beads or engraving bone can be tested in the same way.

REFERENCES CITED

Ackerman, Robert E.
1996 Early Maritime Culture Complexes of the Northern Northwest Coast. In *Early Human Occupation in British Columbia, edited by Roy L. Carlson and Luke Dalla Bona*, pp. 123-132. University of British Columbia Press, Vancouver.

Ames, Kenneth M. and Herbert D.G. Maschner
1999 *Peoples of the Northwest Coast: Their Archaeology and Prehistory*. Thames and Hudson, London.

Andrefsky, William
2005 *Lithics: Macroscopic Approaches to Analysis.*, 2nd Ed. Cambridge University Press, New York.

Anthony, J.W., R.A. Bideaux, K.W. Bladh, and M.C. Nichols
2001 *Handbook of Mineralogy*, Mineral Data Publishing, Tucson, Arizona.

Banning, E. B.
2000 *The Archaeologist's Laboratory: the Analysis of Archaeological Data*. Kluwer Academic/Plenum, *New* York.

Beta Analytic, Inc.
2011 Report of Radiocarbon Dating Analyses for Ms. Alison Palmer. Reference #: 307548 for sample WH47N1E14060cm. Beta Analytic, Inc., Miami, FL.

Curtin, Joanne A.,
1999 Mortuary Practices. In *Archaeological Investigations at Tsawwassen, B.C.*, Arcas Consulting Archaeologists Ltd., Vol. IV, Section 4. Prepared for the Construction Branch, South Coast region, Ministry of Transportation and Highways. Burnaby, British Columbia.

Campbell, Sarah, Diana Barg, Brett N. Meidinger, and Todd A. Koetje
2010 *Report of 2005 Field Investigations at Woodstock Farm, Chuckanut Bay, Washington.* Report on File at the Washington State Department of Archaeology and Historic Preservation (DAHP), Olympia, Washington.

Carlson, Roy L.
1996 The Later Prehistory of British Columbia in *Early Human Occupation in British Columbia,* edited by Roy L. Carlson and Luke Dalla Bona, pp. 215-226. University of British Columbia Press. Vancouver.

Croes, Dale R.
1995 *The Hoko River Archaeological Site Complex: The Wet/Dry Site (45CA213), 3,000-1,700 B.P.* Washington State University Press, Pullman.

Croes, Dale R. and Eric, Blinman
1980 Hoko River: A 2500 Year Old Fishing Camp on the Northwest Coast of North America. In *Reports of* Investigation*, No. 58*. Laboratory of Anthropology, Washington State University, Pullman.

Derndarsky, Monika and Göran Ocklind
2001 Some Preliminary Observations on Subsurface Damage on Experimental and Archaeological Quartz Tools using CLSM and Dye. *Journal of Archaeological Science* 28:1149–1158.

Desrosiers, Pierre M. and Daniel Gendron
2004 The GhGk-63 Site: A Dorset Occupation in Southeastern Hudson Bay, Nunavik. *Canadian Journal of Archaeology* 28:75-99.

Driscoll, Killian
2010 Vein Quartz in Lithic Traditions: An Analysis based on Experimental Archaeology. *Journal of Archaeological Science* 38:734-745.

2009 Exploring the C*haîne Opératoires* in Irish Quartz Lithic Traditions: Current Research. *Internet Archaeology* 26, from http://intarch.ac.uk/journal/issue26/driscollb_index.html.

Dubeau, Matthew A.
2012 *Late-Holocene Mammal Use in the Salish Sea: A Case Study from the Cherry Point Site (45WH1), Northwestern Washington.* Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

DuBois, Thomas H.
2009 *An Introduction to Shamanism.* Cambridge University Press, New York.

Eliade, Mircea
1972 *Shamanism - Archaic Techniques of Ecstasy*. 2nd ed. Princeton University Press, Princeton, Massachusetts.

Fagan, Brian M.
1991 *Ancient North America: The Archaeology of a Continent.* Thames and Hudson.

Flegler, S, J. Heckman and K. Klomparens
1995 *Scanning and Transmission Electron Microscopy*. New York: Oxford University Press.

Flenniken, J. Jeffrey
1981 *Replicative System Analysis: A Model Applied to the Vein Quartz Artifacts from the Hoko River Site.* Reports of Investigation No. 59, Laboratory of Anthropology, Washington State University, Pullman.

Goebel, Ted and Ian Buvit
2011 *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*. Texas A & M University Press, College Station.

Grace, R., I. D. G. Graham, and M. H. Newcomer
1985 The Quantification of Microwear Polishes. *World Archaeology* 17(1):112-120.

Greaves, Sheila
1991 *The Organization of Microcore Technology in the Canadian Southern Interior Plateau.* Unpublished Ph.D. dissertation, University of British Columbia, Vancouver.

Hamilton, W.R., A.R. Woolley, and A.C. Bishop
1978 *The Larousse Guide to Minerals, Rocks, and Fossils*. Larousse, New York.

Helwig, Kate, Valery Monahan, and Jennifer Poulin
2008 The Identification of Hafting Adhesive on a Slotted Antler Point from a Southwest Yukon Ice Patch. *American Antiquity* 73:279-288.

Hicks, Brent
1991 *Interpreting the Role of Microblades in Northwest Coast Aboriginal Sites.* Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

Hickok, Andrew W., William A. White, Kim Recalma-Clutesi, Steven R. Hamm, and Hayley E. Kanipe
2010 Mortuary Evidence of Coast Salish Shamanism? *The Canadian Journal of Archaeology* 34:240-264.

Hutchings, Karl W.
1996 The Namu Obsidian Industry. In *Early Occupations in British Columbia*, edited by Roy L. Carlson and Luke Dalla Bona, pp. 167-176. University of British Columbia Press, Vancouver.

Igreja, Marina de Araujo

2009 Use-wear Analysis of Non-flint Stone Tools using DIC Microscopy and Resin Casts: A Simple and Effective Technique. In *Recent Functional Studies on Non-flint Stone Tools: Methodological Improvements and Archaeological Inferences*, pp.1–20. Lisboa, May 23-25, 2008: Proceedings of the Workshop.

Kalweit, Holger

1992 *Shamans, Healers, and Medicine Men.* Shambhala Publications, Boston, Massachusetts.

Keeley, Lawrence H.

1980 *Experimental Determination of Stone Tool Uses*. University of Chicago Press.

Kimball, Larry R.

2013 Microwear Analysis of Archaic Quartz Tools from 18MO595, Maryland. Technical Microwear Report for URS Corporation.

2008 Microwear Analysis of Archaic and Woodland Tools from 36Hu187, Pennsylvania. Technical Microwear Report for Heberling Associates, Inc.

1994 An Introduction to Methodological and Substantive Contributions of Microwear Analysis. *Lithic Technology* 19(2):81-82.

Kimball, Larry R., John F. Kimball and Patricia E. Allen

1995 Microwear Polishes as viewed through the Atomic Force Microscope. *Lithic Technology* 20(1):6-28.

Knutsson, Kjel

1988 *Patterns of Tool Use: Scanning Electron Microscopy of Experimental Quartz Tools.* Societas Archaeologica Upsaliensis, Department of Archaeology, Uppsala University, Sweden.

Kuzmin, Yaroslav V., Susan G. Keates, Chen Shen (editors)

2007 *Origin and Spread of Microblade Technology in Northern Asia and North America.* Simon Fraser University, pp. 7. Archaeology Press, Burnaby, British Columbia.

Lagestee, Todd

2012 *Crystal Clear: Not All Microblades are Equal, Experimental Archaeology of Quartz Crystal Microblades and Inferences of Locarno Beach Phase Production in the Gulf of Georgia Area*. Paper presented at the 66th Annual Northwest Anthropological Conference, Portland, Oregon.

Lewis, Ian

2013 *Chasing Clusters: Analysis of Activity Areas to Determine Site Type at the Locarno Beach Phase (3500-2400 BP) Site 45WH55, Chuckanut Bay, Washington.* Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

MacDonald, Brandi Lee

2008 *Ochre Procurement and Distribution on the Central Coast of British Columbia.* Master's Thesis, McMaster University, Hamilton, Ontario.

Mason, Ronald J. and Gregory Perino

1961 Microblades at Cahokia, Illinois. *American Antiquity* 26:553-557.

Mather, Camille

2009 *Locarno Beach Period (3500-2400BP) Settlement and Subsistence in the Gulf of Georgia Region: A Case Study from site 45SK46, Deception Pass, Washington*. Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

Matson, R. G. and Gary Coupland

1995 *The Prehistory of the Northwest Coast*. Academic Press, San Diego, California.

Mitchell, Donald H.

1990 Prehistory of the Coasts of Southern British Columbia and Northern Washington. In Northwest Coast, edited by Wayne Suttles, pp. 340-358. *Handbook of North American Indians, Vol. 7*, William C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C.

Montgomery, J. A.

1979 *Prehistoric Subsistence at Semiahmoo Spit 45 WH 17*. Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

Odell, George H.

2004 *Lithic Analysis.* Kluwer Academic/Plenum Publishers, New York.

Reher, Charles A. and George C. Frison

1991 Rarity, Clarity, Symmetry: Quartz Crystal Utilization in Hunter-Gatherer Stone Tool Assemblages. In *Raw Material Economies among Pre-Historic Hunter Gatherers*. edited by Anta Montet-White and Steven Holen. pp 375-397. University of Kansas Press, Lawrence.

Rorabaugh, Adam N.

2009 *Barbed Bone and Antler Technologies: Cultural Transmission and vatiation in the Gulf of Georgia, Northwest North America*. Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

Smith, Nicole Fenwick

1997 *A Geochemical Approach to Understanding Raw Material Use and Stone Tool Production at the Richardson Island Archaeological Site, Haida Gwaii, British Columbia.* Unpublished M.A. Thesis, The University of Victoria, British Columbia.

Spear, Robert

1977 *A Prehistoric Site Cluster in Western Whatcom County*. Unpublished M.A. Thesis, Department of Anthropology, Western Washington University, Bellingham.

Sussman, Carole

1985 Microwear on Quartz: Fact or Fiction?. *World Archaeology* 17:101-111.

1988 *A Microscopic Analysis of Use-wear and Polish Formation on Experimental Quartz Tools*. British Archaeological Reports International 395, Oxford.

Thomas, David Hurst

1985 Archaeology of Hidden Cave, Nevada. *Anthropological Papers of the American Museum of Natural History* 61 (1).

Trueblood, Anne Brodzky, Rose Danesewich, and Nick Johnson

1977 *Stones, Bones and Skin: Ritual and Shamanic Art*. The Society for Art Publications, Toronto, Ontario.

Walker, Sara

1999 The Microblade Industry at 45CA426, Component II. In *The SR101 Sequim Bypass Archaeological Project: Mid- to Late- Holocene Occupations on the Northern Olympic Peninsula, Clallam County, Washington*. Edited by Vera E. Morgan. Vol. 1 pp 14.1-14.17. Cheney, Washington. Eastern Washington University.

Whittaker, John C.

1994 *Flintknapping: Making and Understanding Stone Tools*. University of Texas Press, Austin.

Wreschner, Ernst E., Ralph Bolton, Karl W. Butzer, Henri Delporte, Alexander Häusler, Albert Heinrich, Anita Jacobson-Widding, Tadeusz Malinowski, Claude Masset, Sheryl F. Miller, Avraham Ronen, Ralph Solecki, Peter H. Stephenson, Lynn L. Thomas, and Heinrich Zollinger
1980 Red Ochre and Human Evolution: A Case for Discussion [and Comments and Reply]. *Current Anthropology* 21(5):631-44.

APPENDIX A: ATTRIBUTE ANALYSIS FORM

Rachael Kannegaard — Quartz Crystal Microblade Thesis Research — 2013

Artifact Attribute Analysis Form

Site: _________________

Cat #: ________________

Length: ______________

Width: _______________

Thickness: ___________

Weight: ______________

Cross Section: Triangular
Trapezoidal
Lenticular

Sketch	
Dorsal	**Ventral**
Proximal **Cross Section**	
Distal **Cross Section**	

Artifact type:	Microblade	Core	Flake	Shatter	
Termination:	Feather	Hinge	Step	Modified	NA
Blade/flake portion:	Complete	Proximal	Distal	Medial	NA
Cortex:	Absent	Dorsal	Other		
Attrition:	R. Lateral	L. Lateral	Distal	Proximal	
Visible residue:	Absent	Present	Colors:		

Comments:

APPENDIX B: MICROWEAR ANALYSIS FORM

Microwear Analysis Form

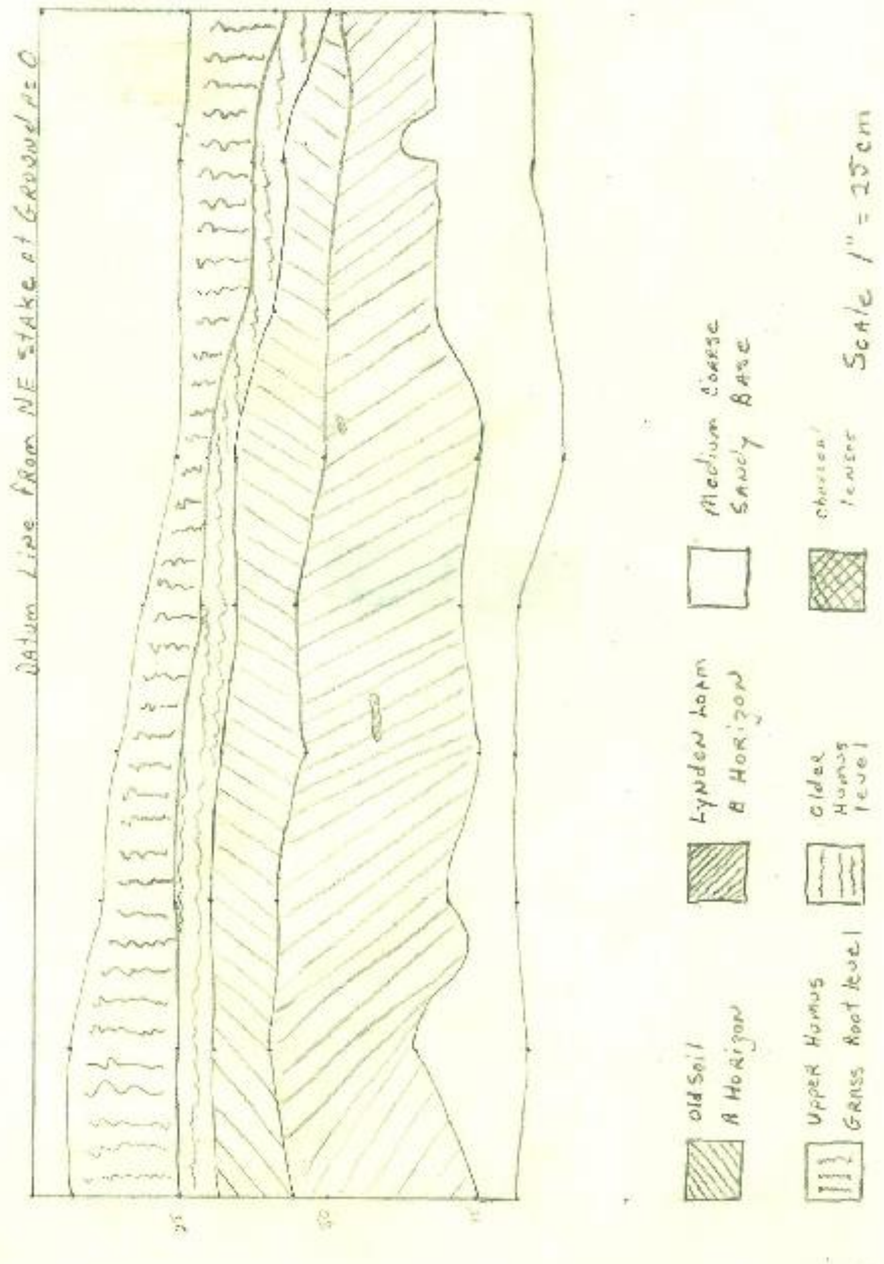
Site #	Artifact #	Artifact Type	Wear Location	Wear (P/A)	Scar Type (SC, HM, ST, SCHM)	Orientation (P, O)	Comments
			R1				
			R2				
			R3				
			D				
			L1				
			L2				
			L3				
			R1				
			R2				
			R3				
			D				
			L1				
			L2				
			L3				

APPENDIX C: WALL PROFILES OF N1W1 AND N1W2

WWSC BURIAL AND FEATURE RECORD

TRENCH:	SITE NO.: 45WH59
CUT: N1W1	DATE: 6/3/76
BURIAL:	EXCAVATOR: Pint, Zelenka, Montgomery
FEATURE NO.: Profile of cut	LEVEL OR DEPTH:

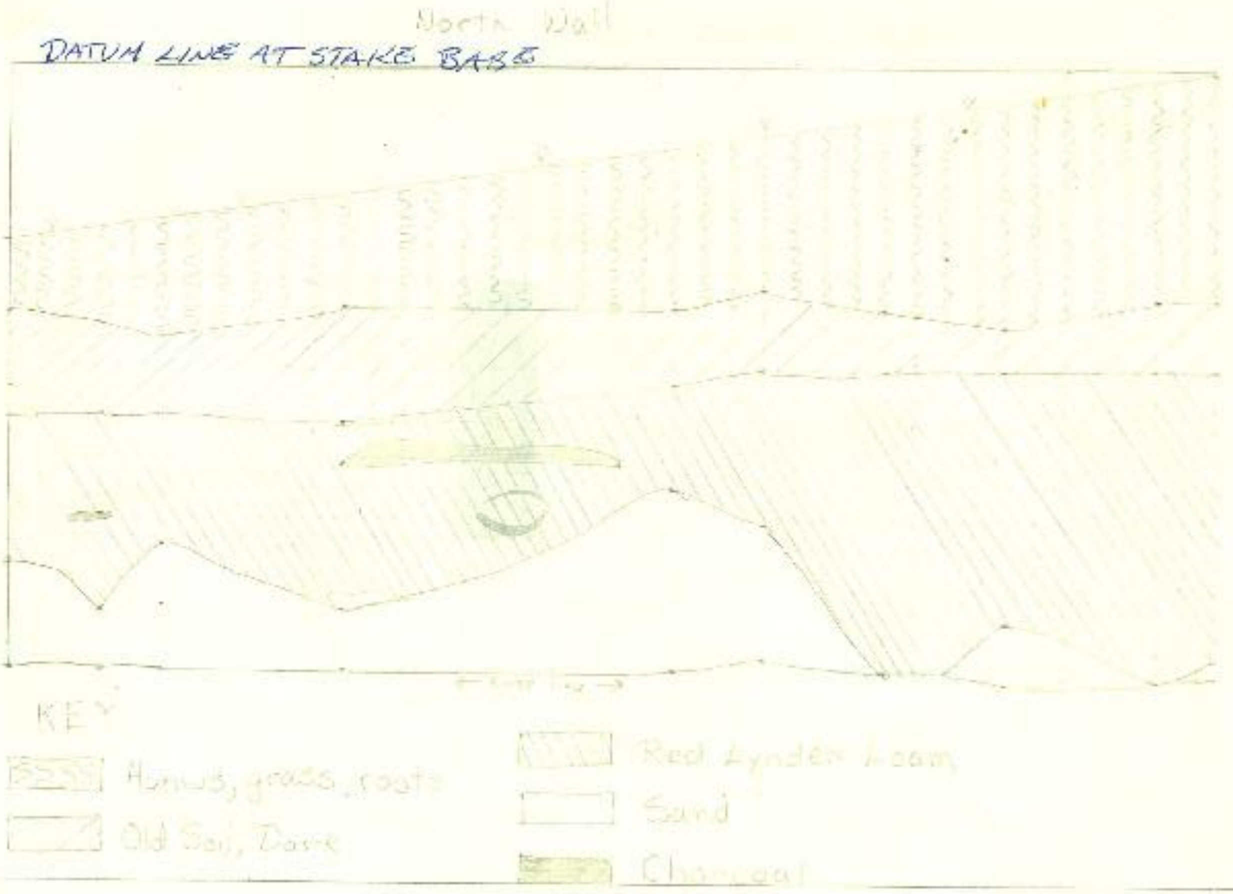
East wall of N1W1 From datum level to



WASH BURIAL AND FEATURE RECORD

TRENCH:
CUT: N 1/2 22
BURIAL:
FEATURE NO.: [illegible]
SITE NO.: 45 WH 22
DATE: 5/21/[illegible]
RECORDER: [illegible]
LEVEL OR DEPTH:

Scale 4" = 1m 1" = 25cm



APPENDIX D: RESULTS OF BOTANICAL ANALYSIS (GAHR 2014)

D. ANN GAHR
2028 Cleveland Street
Eugene, OR 97405
(541) 344-5453 (home)
541-968-9777 (cell)
e-mail: anngahr@gmail.com

11 January 2014

Via First Class Mail
E-mail: kannegr@students.wwu.edu

Rachael Kannegaard
Department of Anthropology
Western Washington University
516 High Street
Bellingham, WA 98225

Re: 45WH59—Charcoal Analysis for Carbon-14 Dating

Dear Rachael:

This is a brief report on the taxonomic identification of charcoal from two samples designated for carbon-14 dating. The two samples were recovered from archaeological investigations conducted by Robert Spear in 1976 at 45WH59, located in Whatcom County, Washington. The site yielded a rich assemblage of lithic artifacts, including the quartz crystal lithic artifacts which are the focus of the study. Few charcoal samples were collected from the site during excavation, and the site has not yet been dated by radiocarbon dating. The question submitted here was to determine the sufficiency of these samples for radiocarbon dating.

Methods

Samples arrived in good condition. Because these samples were selected for radiocarbon dating, extra cautionary steps were taken to prevent inter-sample contamination and to minimize handling. After weighing sample on Accu-Lab scale (200 g x 0.01 g +/- 0.01 g), specimens were hand selected for analysis. Mechanical separation using sieves was not used.

Wood charcoal specimens greater than 1 mm were prepared for identification by fracturing the individual specimens to expose fresh surfaces on each of three anatomical planes (cross, radial, and tangential). Each surface was examined using a stereoscope with enhanced magnification (28X to 180X) and enhanced illumination. Observations were compared with modern and archaeological reference specimens and a series of anatomical keys for wood (InsideWood 2004; Panshin and de Zeeuw 1980; Phillips 1941; Richter et al. 2004; USDA 2009).

Results

Sample:45WH059/1976/022

Cut: N1W2 Unit: A Level: 40-60 cm Depth: 56 cm cmbs
Coordinates: 2.02 m N of N; 5.06 m W of W

Sample weight: 4.26 g. including sedimentary matrix

Overall charcoal in this sample was highly degraded and comprised into an aggregate of very small charcoal particle size (<0.5 mm) and sedimentary matrix. Little cellular structure remained, except as indicated below. The preserved plant tissue represents parenchyma tissue such as from geophytes, herbaceous dicot (hardwood) bark, conifer (cf. *Tsuga* sp. and unidentified conifer). This sample was divided into four types and bagged to facilitate choice of radiocarbon methods.

1) Sedimentary matrix with a high charcoal load of < 0.5 mm. Charcoal was unidentifiable. 6.11 g +/-0.01 g.
2) Charcoal aggregate comprised of mostly unidentifiable crushed charcoal. Some fragments of conifer, some bark-like anatomy, some parenchyma tissue. Note there is considerable fine root hair intrusion.
3) Possible geophyte epidermal tissue; dicot bark; 5 specimens 0.09 g +/1 0.01 g.
4) Conifer unidentifiable, 1 specimen; cf. *Tsuga* sp., 1 specimen. <0.01 g.

Sample: 45WH059/1976/064
Acc. 61
Cut: N1W1 Unit: C Level: 40-60 cm Depth: 56 cm cmbs
Coordinates: 2.5 m N of N; 0.8 m W of W

Sample weight: 23.07 g, including sedimentary matrix

Pseudotsuga sp. 63 specimens 9.2 g.
Compression wood, 46 specimens
False ring, 15 specimens
Larger specimens with 20 – 25 growth increments
Growth increments highly variable. Some specimens reveal ring shakes, twisting tracheids, and traumatic schizogenous resin canals.
Note: fine root hair penetration present, but not frequent.
Matching of growth increments, false growth increment, and schizogenous resin canals indicate that most likely fewer than three separate trees, or parts of a tree, were represented.

Discussion

The two samples have different considerations as to their desirability for radiocarbon dating.

Sample 022: This is a small sample, suitable for AMS only, based on weight. I removed the conifer specimens from the sample. However, I do not know what portion of the highly degraded portions is comprised of conifer. However the presence of young dicot bark and parenchyma cells would eliminate the "old wood" problem.

Sample 064: This larger sample entirely composed of Douglas-fir could be dated by standard methods. However, Douglas-fir is a long-lived species, some reaching 1,000 or more years old in Northwestern Washington region. The possibility that the sample has an "old wood problem" could lead to discarding this as an appropriate sample for radiocarbon dating. However, ecological and functional variation revealed in the wood anatomy lend an argument to this sample being considered as potentially promising. It is more likely than not that these specimens derived from branch wood as evidenced from the high ratio of compression wood (73%). Compression wood is a dense wood that forms on the lower or underside of branches or leaning trunks. Given that Douglas fir self-prunes limbs as it grows, the sample most likely represent a fallen branch. The wood from this sample was in excellent condition and had no evidence of pre-charring degradation. In the humid temperate environment of Western Washington, this would most likely signify that the wood was collected fairly shortly after it fell or was cut. Some specimens contained 20 to 25 growth increments indicating that the wood was older than that. Furthermore, the specimens in the sample share individual characteristics such as matching growth increments (a pattern of narrow and wide growth increments); false growth increment (result of temporary cessation of growth caused by a variety of factors including late spring freeze, drought followed by rains, or insect defoliation); traumatic resin canals (resulting from injury). Based on these shared histories and identical preservation of the specimens in the sample I believe that no more than three separate branches compose this assemblage. It is most likely that this sample derived from a single burn event. This would increase the precision of the date.

I hope that this information can assist you in selecting your samples for radiocarbon dating. Please contact me if you have any questions.

Sincerely yours,

D. Ann Gahr

REFERENCES CITED

InsideWood 2004 Inside Wood -Inside Wood Database. *Inside Wood*. http://insidewood.lib.ncsu.edu/search.5.

Panshin, Alexis John, and Carl de Zeeuw 1980 *Textbook of Wood Technology*. 4th ed. New York: McGraw-Hill.

Phillips, E.W.J. 1941 The identification of coniferous woods by their microscopic structure. *Journal of the Linnean Society of Botany* 52: 259–320.

Richter, H.G., D. Grosser, I. Heinz, and P.E. Gasson 2004 IAWA List of Microscopic Features for Softwood Identification. *IAWA Journal* 25, no. 2: 1–70.

USDA 2009 USDA Plants. August 1. http://plants.usda.gov/.

APPENDIX E: RESULTS OF RADIOMETRIC DATING (BETA ANALYTIC INC. 2014)

BETA

Consistent Accuracy . . .
. . . Delivered On-time

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0964
Beta@radiocarbon.com
www.radiocarbon.com

Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

February 12, 2014

Dr. Rachael Kannegaard
Western Washington
University
Department of Anthropology, MS9083
516 High Street
Bellingham, WA
98225 USA

RE: Radiocarbon Dating Results For Samples WH59N1W14060,
WH59N1W24060 Dear Dr. Kannegaard:

Enclosed are the radiocarbon dating results for two samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. The report sheet contains the dating result, method used, material type, applied pretreatment and two-sigma calendar calibration result (where applicable) for each sample.

All results (excluding some inappropriate material types) which are less than about 42,000 years BP and more than about ~250 BP include a calendar calibration page (also digitally available in Windows metafile (.wmf) format upon request). Calibration is calculated using the newest (2009) calibration database with references quoted on the bottom of the page. Multiple probability ranges may appear in some cases, due to short-term variations in the atmospheric 14C contents at certain time periods. Examining the calibration graph will help you understand this phenomenon. Don’t hesitate to contact us if you have questions about calibration.

We analyzed these samples on a sole priority basis. No students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

The cost of the analysis was charged to the VISA card provided. Thank you. As always, if you have any questions or would like to discuss the results, don’t hesitate to contact me.

Sincerely,

Darden Hood

Digital signature on file

BETA

Consistent Accuracy . . .
. . . Delivered On-time

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0964
Beta@radiocarbon.com
www.radiocarbon.com

Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

February 12, 2014

Dr. Rachael Kannegaard
Western Washington University
Department of Anthropology, MS9083
516 High Street
Bellingham, WA 98225
USA

RE: Radiocarbon Dating Results For Samples WH59N1W14060, WH59N1W24060

Dear Dr. Kannegaard:

Enclosed are the radiocarbon dating results for two samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. The report sheet contains the dating result, method used, material type, applied pretreatment and two-sigma calendar calibration result (where applicable) for each sample.

All results (excluding some inappropriate material types) which are less than about 42,000 years BP and more than about ~250 BP include a calendar calibration page (also digitally available in Windows metafile (.wmf) format upon request). Calibration is calculated using the newest (2009) calibration database with references quoted on the bottom of the page. Multiple probability ranges may appear in some cases, due to short-term variations in the atmospheric 14C contents at certain time periods. Examining the calibration graph will help you understand this phenomenon. Don't hesitate to contact us if you have questions about calibration.

We analyzed these samples on a sole priority basis. No students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

The cost of the analysis was charged to the VISA card provided. Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file

BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Rachael Kannegaard — Report Date: 2/12/2014

Western Washington University — Material Received: 1/27/2014

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 371368	2740 +/- 30 BP	-24.0 o/oo	2760 +/- 30 BP

SAMPLE : WH59N1W14060
ANALYSIS : RadiometricPLUS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 980 to 830 (Cal BP 2920 to 2780)

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 371369	320 +/- 30 BP	-24.3 o/oo	330 +/- 30 BP

SAMPLE : WH59N1W24060
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 1460 to 1650 (Cal BP 490 to 300)

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

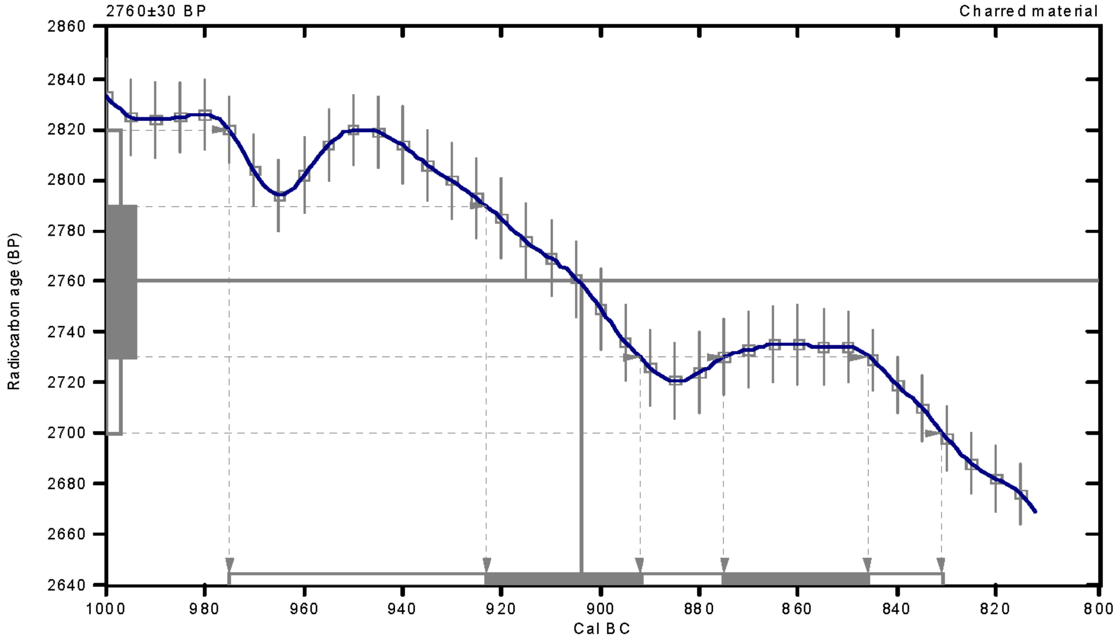
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24:lab. mult=1)

Laboratory number:	**Beta-371368**
Conventional radiocarbon age:	**2760±30 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 980 to 830 (Cal BP 2920 to 2780)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 900 (Cal BP 2850)
1 Sigma calibrated results: (68% probability)	Cal BC 920 to 890 (Cal BP 2870 to 2840) and Cal BC 880 to 850 (Cal BP 2820 to 2800)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):1-244, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

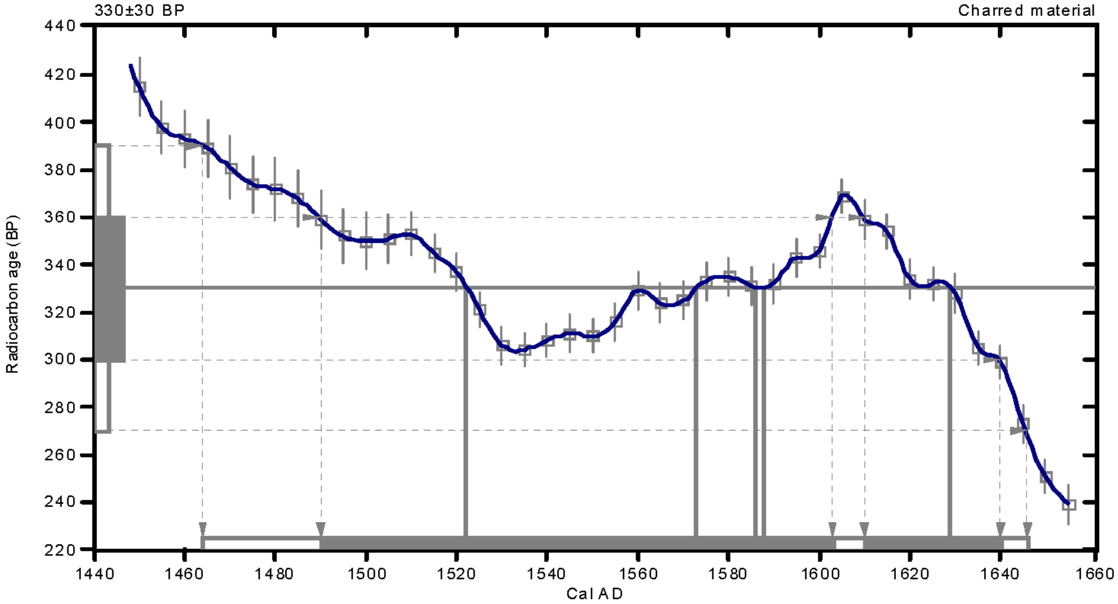
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.3:lab. mult=1)

Laboratory number:	**Beta-371369**
Conventional radiocarbon age:	**330±30 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal AD 1460 to 1650 (Cal BP 490 to 300)**

Intercept data

Intercepts of radiocarbon age with calibration curve:	Cal AD 1520 (Cal BP 430) and Cal AD 1570 (Cal BP 380) and Cal AD 1590 (Cal BP 360) and Cal AD 1590 (Cal BP 360) and Cal AD 1630 (Cal BP 320)
1 Sigma calibrated results: (68% probability)	Cal AD 1490 to 1600 (Cal BP 460 to 350) and Cal AD 1610 to 1640 (Cal BP 340 to 310)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):1-244, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

APPENDIX F: RAW ATTRIBUTE ANALYSIS DATA

Site #	Artifact #	Artifact Type	Termination	Blade Portion	Cortex	Visible Residue	Colors	Cross Section
45SK46	402	M	NA	P	A	P	Dk, R	Trap
45SK46	407	M	Rounded	C	A	P	M, Lt, Dk	Trap
45SK46	1163	M	F	C	A	P	Lt, M	Trap
45SK46	1164	M	F	C	A	P	M, G, Dk	Trap
45SK46	1165	M	F	C	D	P	Dk, M	Trap
45SK46	1166	M	S	C	A	P	R	Trap
45SK46	1167	M	F	C	D	P	Dk, G, Lt, M	L
45SK46	1169	S	NA	NA	A	P	R	Trap
45SK46	1170	S	NA	NA	A	P	Dk, Matte	NA
45SK46	1171	F	NA	NA	A	P	Lt	Tri
45SK46	1172	M	F	C	A	P	Dk, Matte	Tri
45WH01	54	M	S	C	A	A	NA	Tri
45WH01	119	M	NA	P	A	A	NA	Trap, Tri
45WH01	179	M	F	C	A	P	Dk	Trap
45WH01	1275	C	NA	NA	O	P	W, Dk, B, Bl	Trap
45WH17	1435	C	NA	NA	D	P	Dk	L
45WH47	61	C	NA	NA	O	P	Dk	Trap
45WH55	507	S	NA	NA	A	P	Br, Milky Br.	Trap, Tri
45WH55	612	F	NA	NA	P	P	Bl, Lt. Br.	
45WH55	707	M	H	C	A	P	Dk	Tri, Trap
45WH55	760	M	F	C	A	P	R, Bl, G	Trap, Tri
45WH55	1147	M	NA	M	A	P	Dk. Br	Tri
45WH55	1565	M	NA	P	A	P	Lt. Br	L, Tri
45WH55	1591	M	S	C	D	P	BL, Dk. Br	Trap
45WH55	1817	M	H	C	A	P	Dk. Br, Lt. Br	Trap
45WH55	2413	M	F	C	D	P	Lt. BR	Trap, Tri
45WH59	1	M	S	C	A	P	Br	Trap
45WH59	2	M	S	C	A	P	Br	Trap

45WH59	3	C	NA	NA	O	P	Dk	NA
45WH59	9	M	NA	M	A	P	R, Br	Tri
45WH59	11	S	NA	NA	A	P	M, Lt	L
45WH59	13	M	NA	P	A	P	Bl, Dk, M	Trap
45WH59	14	M	H	C	A	P	Br, Dk	Trap
45WH59	15	M	H	C	A	P	Lt	Trap
45WH59	16	M	F	C	A	P	M, Lt	Trap
45WH59	17	M	NA	M	A	P	Dk	Trap
45WH59	24	M	S	C	D	P	Dk	Trap
45WH59	25	M	NA	M	A	P	Dk	Trap
45WH59	27	C	NA	NA	D	A	NA	Trap
45WH59	30	M	NA	M	A	A	NA	Trap
45WH59	31	M	NA	P	D	P	Lt, M	Trap
45WH59	33	C	NA	NA	D	A	NA	Trap
45WH59	35	F	NA	NA	D	P	R, Br	NA
45WH59	36	M	NA	P	D	P	?	Trap
45WH59	37	M	F	C	D	P	Lt. Br, Gr/Bl., R/Br.	Tri
45WH59	39	M	NA	M	D	A	NA	L
45WH59	40	F	NA	NA	D	P	R	Trap
45WH59	41	C	NA	NA	D	P	Bl, Br	L
45WH59	42	M	NA	P	A	P	Lt, R	Trap
45WH59	44	M	F	C	A	A	NA	L, Tri
45WH59	45	M	NA	P	A	P	Dk, Lt	Tri
45WH59	46	M	H	C	A	P	Lt	Trap
45WH59	47	F	NA	NA	A	P	R, Dk	NA
45WH59	48	M	NA	M	A	A	NA	Trap
45WH59	50	F	NA	NA	D	P	R	Trap
45WH59	56	M	F	C	A	A	NA	Tri
45WH59	57	M	S	C	A	P	Lt. Br, R	Tri, Trap

45WH59	59	M	S	C	D	P	R/Br.	Trap
45WH59	60	M	NA	P	A	P	RB	Trap
45WH59	62	M	NA	P	A	A	NA	Trap
45WH59	63	F	NA	NA	A	P	Dk, Br	NA
45WH59	65	F	NA	NA	D	P	Dk	NA
45WH59	67	M	F	C	A	P	Lt, M	Trap
45WH59	74	M	F	C	D	P	Br.	Tri, Trap
45WH59	75	M	NA	P	A	P	R	Trap
45WH59	176	C	NA	NA	D	P	R, Bl.	NA
45WH59	210	S	NA	NA	D	P	Dk, W	NA

APPENDIX G: MEASUREMENT DATA

Site #	Artifact #	L 1	L 2	L 3	Length Mean	S.D.	W 1	W 2	W 3	Width Mean	S.D.	T 1	T 2	T 3	Thickness Mean	S.D.	Weight
45SK46	1171	6.2	6.33	6.22	6.25	0.07	5.22	5.39	4.98	5.20	0.21	1.29	1.32	1.24	1.28	0.04	0.31
45SK46	402	10.07	10.16	9.87	10.03	0.15	7.92	8.01	8.07	8.00	0.08	3.7	3.95	3.93	3.86	0.14	0.59
45SK46	407	11.06	10.93	10.63	10.87	0.22	4.37	4.3	4.45	4.37	0.08	1.38	1.4	1.29	1.36	0.06	0.34
45SK46	1163	12.07	12.19	12.09	12.12	0.06	4.93	5.1	5.08	5.04	0.09	1.2	1.26	1.1	1.19	0.08	0.28
45SK46	1164	7.78	8.05	8.07	7.97	0.16	4.43	4.53	4.52	4.49	0.06	1.64	1.58	1.41	1.54	0.12	0.31
45SK46	1165	13.27	13.42	13.46	13.38	0.10	6.14	6.17	6.04	6.12	0.07	1.62	1.54	2.99	2.05	0.82	0.35
45SK46	1166	14.14	14.05	14.04	14.08	0.06	6.14	6.26	6.02	6.14	0.12	2.35	2.11	3.64	2.70	0.82	0.48
45SK46	1167	11.8	11.86	11.86	11.84	0.03	5.81	6.06	5.68	5.85	0.19	1.86	1.76	2.94	2.19	0.65	0.34
45SK46	1172	7.15	7.01	6.49	6.88	0.35	4.37	4.16	4.17	4.23	0.12	0.76	0.97	1.04	0.92	0.15	0.29
45SK46	1168	11.52	11.91	11.42	11.62	0.26	6.65	7.06	6.63	6.78	0.24	1.71	1.7	1.47	1.63	0.14	0.38
45SK46	1169	8.41	8.42	8.41	8.41	0.01	6.35	6.31	6.51	6.39	0.11	1.37	1.17	1.51	1.35	0.17	0.33
45SK46	1170	7.47	7.35	7.02	7.28	0.23	4.29	4.45	4.56	4.43	0.14	1.19	1.34	1.2	1.24	0.08	0.30
45WH01	1275	22.51	22.53	23.45	22.83	0.54	16.27	18.15	16.96	17.13	0.95	16.97	16.98	16.58	16.84	0.23	7.89
45WH01	54	11.98	12.37	11.72	12.02	0.33	5.57	5.72	5.9	5.73	0.17	2.39	2.46	3.94	2.93	0.88	0.36
45WH01	119	13.43	13.49	13.18	13.37	0.16	6.5	6.44	6.14	6.36	0.19	1.85	1.73	1.69	1.76	0.08	0.34
45WH01	179	21.15	20.88	20.86	20.96	0.16	4.13	4.02	3.86	4.00	0.14	1.56	1.78	1.37	1.57	0.21	0.30
45WH17	1435	25.47	27.08	26.38	26.31	0.81	18.84	18.29	17.83	18.32	0.51	6.81	6.73	6.77	6.77	0.04	3.83
45WH47	61	16.53	16.6	15.93	16.35	0.37	8.76	8.63	9.09	8.83	0.24	4.83	4.7	4.82	4.78	0.07	0.96
45WH55	612	8.98	9.41	8.94	9.11	0.26	6.5	6.46	6.44	6.47	0.03	2.84	2.84	2.43	2.70	0.24	0.30
45WH55	707	16.48	16.11	16.37	16.32	0.19	6.94	7.03	7	6.99	0.05	2.1	1.8	3.43	2.44	0.87	0.31
45WH55	760	25.43	25.33	24.92	25.23	0.27	5.3	5.71	5.58	5.53	0.21	3.24	1.81	3.63	2.89	0.96	0.44
45WH55	1147	10.85	11.35	11.2	11.13	0.26	4.03	3.9	3.74	3.89	0.15	1.5	1.5	1.36	1.45	0.08	0.10
45WH55	1565	7.12	7.15	7.14	7.14	0.02	4.26	4.13	4.14	4.18	0.07	1.07	1.28	0.91	1.09	0.19	0.13
45WH55	1591	16.83	16.71	16.52	16.69	0.16	4.51	4.05	4.14	4.23	0.24	1.46	1.48	1.37	1.44	0.06	0.23
45WH55	1817	20.43	20.29	20.29	20.34	0.08	4.58	4.76	4.21	4.52	0.28	1.63	1.52	1.53	1.56	0.06	0.24
45WH55	2413	8.2	8.2	8.04	8.15	0.09	2.89	2.53	2.6	2.67	0.19	0.97	0.9	0.74	0.87	0.12	0.02
45WH55	507	11.21	10.84	11.04	11.03	0.19	8.86	7.9	8.68	8.48	0.51	1.69	1.72	1.66	1.69	0.03	0.33
45WH59	3	7.96	7.83	7.51	7.77	0.23	7.67	7.68	6.98	7.44	0.40	4.23	4.38	4.14	4.25	0.12	0.43

45WH59	27	14.55	14.95	15.07	14.86	0.27	11.81	11.58	11.99	11.79	0.21	5.72	5.68	5.7	5.70	0.02	1.32
45WH59	33	10.36	10.96	10.87	10.73	0.32	7.2	6.93	7.62	7.25	0.35	6.65	7.06	6.64	6.78	0.24	0.82
45WH59	41	14.9	14.62	14.89	14.80	0.16	15.03	14.84	14.71	14.86	0.16	5.08	5.64	5.75	5.49	0.36	1.51
45WH59	176	9.87	10.17	9.54	9.86	0.32	6.33	6.21	6.27	6.27	0.06	3.6	3.49	3.75	3.61	0.13	0.19
45WH59	35	8.89	8.94	8.9	8.91	0.03	7.36	7.68	7.57	7.54	0.16	4.01	3.84	3.68	3.84	0.17	0.34
45WH59	40	15.02	16.09	15.91	15.67	0.57	10.69	10.74	10.6	10.68	0.07	5.64	5.11	5.25	5.33	0.27	0.87
45WH59	47	8.54	8.53	8.51	8.53	0.02	5.64	6.22	5.57	5.81	0.36	1.84	1.46	1.37	1.56	0.25	0.08
45WH59	50	9.16	9.31	9.28	9.25	0.08	7.86	8.17	8.41	8.15	0.28	3.43	3.83	3.29	3.52	0.28	0.28
45WH59	63	4.93	5.29	5.08	5.10	0.18	5.46	4.84	4.66	4.99	0.42	0.74	0.67	0.83	0.75	0.08	0.05
45WH59	65	5.41	5.8	5.54	5.58	0.20	4.03	4.94	4.45	4.47	0.46	1.18	1.36	1.41	1.32	0.12	0.04
45WH59	1	13.93	14.1	14.12	14.05	0.10	5.33	5.65	5.34	5.44	0.18	1.59	1.47	1.56	1.54	0.06	0.22
45WH59	2	11.81	11.92	11.87	11.87	0.06	6.69	6.83	6.93	6.82	0.12	2.62	2.64	2.13	2.46	0.29	0.24
45WH59	9	5.45	5.15	5.6	5.40	0.23	4.29	4.17	4.36	4.27	0.10	0.75	0.83	0.84	0.81	0.05	0.14
45WH59	13	7.34	7.5	6.91	7.25	0.31	4.46	4.26	4.2	4.31	0.14	1.26	1.25	1.18	1.23	0.04	0.16
45WH59	14	13.43	13.21	13.19	13.28	0.13	6.49	5.95	5.88	6.11	0.33	2.13	1.99	1.99	2.04	0.08	0.20
45WH59	15	17.2	17.14	17.15	17.16	0.03	5.11	4.96	5.02	5.03	0.08	1.96	1.3	1.96	1.74	0.38	0.17
45WH59	16	18.85	18.94	18.92	18.90	0.05	5	4.76	4.69	4.82	0.16	1.22	1.2	1.15	1.19	0.04	0.26
45WH59	17	8.97	7.08	9.28	8.44	1.19	1.7	1.86	1.86	1.81	0.09	9.32	6.63	0.14	5.36	4.72	0.06
45WH59	24	8.57	8.94	8.98	8.83	0.23	4.5	4.33	4.65	4.49	0.16	1.22	1.36	1.38	1.32	0.09	0.13
45WH59	25	4.92	5.28	4.49	4.90	0.40	5.19	4.65	5.6	5.15	0.48	1.12	1.15	0.85	1.04	0.17	0.08
45WH59	30	7.53	7.66	7.62	7.60	0.07	5.54	5.76	5.52	5.61	0.13	1.1	1.05	0.97	1.04	0.07	0.17
45WH59	31	8.46	8.27	8.68	8.47	0.21	3.64	3.55	3.5	3.56	0.07	1.1	1.07	1.04	1.07	0.03	0.05
45WH59	36	7.48	8.02	7.49	7.66	0.31	3.61	3.7	3.61	3.64	0.05	0.84	1.21	0.77	0.94	0.24	0.14
45WH59	37	21.11	21.17	20.85	21.04	0.17	5.22	5.87	4.05	5.05	0.92	1.89	1.24	2	1.71	0.41	0.13
45WH59	39	5.07	5.11	5.09	5.09	0.02	3.36	3.22	3.22	3.27	0.08	0.71	0.86	0.67	0.75	0.10	0.14
45WH59	42	9.86	9.96	9.94	9.92	0.05	7.54	7.62	7.71	7.62	0.09	2.71	2.81	2.87	2.80	0.08	0.18
45WH59	44	11.29	11.41	11.14	11.28	0.14	4.63	4.57	4.46	4.55	0.09	1.02	0.94	1.02	0.99	0.05	0.17
45WH59	45	5.46	6.25	4.77	5.49	0.74	4.4	4.7	6.67	5.26	1.23	1.19	1.76	1.27	1.41	0.31	0.04
45WH59	46	9.57	9.85	9.58	9.67	0.16	4.99	4.97	4.94	4.97	0.03	1.39	1.26	1.48	1.38	0.11	0.09
45WH59	48	5.53	5.52	5.47	5.51	0.03	4.1	4.07	3.84	4.00	0.14	0.6	0.88	0.49	0.66	0.20	0.16
45WH59	56	15.98	15.97	15.97	15.97	0.01	4.82	4.93	5.08	4.94	0.13	1.53	1.44	0.82	1.26	0.39	0.24
45WH59	57	9.22	8.86	8.68	8.92	0.27	5.35	5.26	5.48	5.36	0.11	1.62	1.58	1.54	1.58	0.04	0.13
45WH59	59	17.02	17.12	17.14	17.09	0.06	6.73	7.18	6.65	6.85	0.29	2.15	2.04	1.96	2.05	0.10	0.34
45WH59	60	10.5	10.73	10.54	10.59	0.12	5.48	5.65	5.5	5.54	0.09	1.74	1.67	1.79	1.73	0.06	0.17
45WH59	62	13.27	13.47	13.9	13.55	0.32	3.58	3.74	3.75	3.69	0.10	0.97	1.03	0.88	0.96	0.08	0.24

45WH59	67	12.45	12.21	11.79	12.15	0.33	4.92	4.91	4.81	4.88	0.06	1.33	1.22	1.35	1.30	0.07	0.07
45WH59	74	14.05	13.9	13.93	13.96	0.08	3.42	3.3	3.35	3.36	0.06	0.79	0.67	0.84	0.77	0.09	0.13
45WH59	75	8.71	8.94	8.67	8.77	0.15	7.26	7.19	7.21	7.22	0.04	1.47	1.74	1.01	1.41	0.37	0.09
45WH59	11	7.65	7.47	7.56	7.56	0.09	6.5	7.53	5.53	6.52	1.00	1.42	1.27	1.31	1.33	0.08	0.16
45WH59	210	11.51	12.27	12.36	12.05	0.47	12.1	11.7	12.03	11.94	0.21	4.27	4.9	4.02	4.40	0.45	0.50

APPENDIX H: COMPLETE BLADE ANALYSIS

Site	Artifact #	Artifact Type	Wear Location	Wear (P/A)	Scar Type (HM, SC, ST)	Orient. (P, O)
45SK46	407	C	D	A		
45SK46	407	C	L1	P	SCHM	P
45SK46	407	C	L2	P	SCHM/ SC	P
45SK46	407	C	L3	P	SC	P
45SK46	407	C	R1	P	SC	P
45SK46	407	C	R2	A		
45SK46	407	C	R3	P	SC	P
45SK46	1163	C	D	A		
45SK46	1163	C	L1	P	SC/HM	P
45SK46	1163	C	L2	P	HM/ SC	P
45SK46	1163	C	L3	P	SC	P
45SK46	1163	C	R1	A		
45SK46	1163	C	R2	A		
45SK46	1163	C	R3	P	HM/ SCHM	P/O
45SK46	1164	C	D	A	A	
45SK46	1164	C	L1	A		
45SK46	1164	C	L2	A		
45SK46	1164	C	L3	A	A	
45SK46	1164	C	R1	A	A	
45SK46	1164	C	R2	A	A	
45SK46	1164	C	R3	A	A	
45SK46	1165	C	D	A		
45SK46	1165	C	L1	P	SCHM	P
45SK46	1165	C	L2	P	SCHM	P
45SK46	1165	C	L3	A		
45SK46	1165	C	R1	A		
45SK46	1165	C	R2	A		
45SK46	1165	C	R3	A		
45SK46	1166	C	D	P	HM	P
45SK46	1166	C	L1	P	SC/ HM	O
45SK46	1166	C	L2	P	HM/ SCHM	P
45SK46	1166	C	L3	P	SCHM/ HM	P
45SK46	1166	C	R1	P	SC/SC	P
45SK46	1166	C	R2	P	SCHM	P
45SK46	1166	C	R3	P	SCHM	P

45SK46	1167	C	D	A		
45SK46	1167	C	L1	P	HM	P
45SK46	1167	C	L2	A		
45SK46	1167	C	L3	P	SC	P
45SK46	1167	C	R1	A		
45SK46	1167	C	R2	A		
45SK46	1167	C	R3	A		
45SK46	1172	C	D	A		
45SK46	1172	C	L1	A		
45SK46	1172	C	L2	P	HM	P
45SK46	1172	C	L3	A		
45SK46	1172	C	R1	A		
45SK46	1172	C	R2	A		
45SK46	1172	C	R3	A		
45WH01	54	C	D	A		
45WH01	54	C	L1	A		
45WH01	54	C	L2	P	SCHM	P
45WH01	54	C	L3	P	SC/ SCHM	PO/ P
45WH01	54	C	R1	A		
45WH01	54	C	R2	A		
45WH01	54	C	R3	P	SC	P
45WH01	179	C	D	P	SC/ HM/ SCHM	P/O
45WH01	179	C	L1	A		
45WH01	179	C	L2	P	HM	P
45WH01	179	C	L3	P	HM	P
45WH01	179	C	R1	P	SC	O
45WH01	179	C	R2	A		
45WH01	179	C	R3	A		
45WH55	707	C	D	A		
45WH55	707	C	L1	P	SC	P
45WH55	707	C	L2	A		
45WH55	707	C	L3	A		
45WH55	707	C	R1	P	SCHM	P
45WH55	707	C	R2	P	SCHM	P
45WH55	707	C	R3	P	SC	P
45WH55	760	C	D	A		

45WH55	760	C	L1	P	SC	O
45WH55	760	C	L2	P	SC/ SC	P
45WH55	760	C	L3	P	SC/SC/ SCHM	P
45WH55	760	C	R1	A		
45WH55	760	C	R2	A		
45WH55	760	C	R3	P	SC	O
45WH55	1591	C	D	P	SCHM	P
45WH55	1591	C	L1	P	SC /SCST	P
45WH55	1591	C	L2	P	SCHM	P
45WH55	1591	C	L3	P	SCHM	P
45WH55	1591	C	R1	A		
45WH55	1591	C	R2	A		
45WH55	1591	C	R3	P	SCHM	P
45WH55	1817	C	D	P	SCHM	P
45WH55	1817	C	L1	P	SCST	P
45WH55	1817	C	L2	P	SCST	P
45WH55	1817	C	L3	P	SC	P
45WH55	1817	C	R1	P	SC	P
45WH55	1817	C	R2	P	SCST	P
45WH55	1817	C	R3	P	SCST/ SCHMST/ SC	P
45WH55	2413	C	D	A		
45WH55	2413	C	L1	A		
45WH55	2413	C	L2	A		
45WH55	2413	C	L3	P	SC	P
45WH55	2413	C	R1	A		
45WH55	2413	C	R2	P	HM	P
45WH55	2413	C	R3	P	SC/ HM	P
45WH59	1	C	D	A		
45WH59	1	C	L1	P	SC	P
45WH59	1	C	L2	P	SC	P
45WH59	1	C	L3	P	SC	P
45WH59	1	C	R1	P	SCHMST	P
45WH59	1	C	R2	P	SCHMST	P
45WH59	1	C	R3	P	SCHMST/ SC	P
45WH59	2	C	D	A		
45WH59	2	C	L1	P	SCHM	P

45WH59	2	C	L2	A		
45WH59	2	C	L3	P	SC	P
45WH59	2	C	R1	A		
45WH59	2	C	R2	A		
45WH59	2	C	R3	A		
45WH59	14	C	D	A		
45WH59	14	C	L1	P	SC	P
45WH59	14	C	L2	P	SCHM/ SC	P
45WH59	14	C	L3	A		
45WH59	14	C	R1	A		
45WH59	14	C	R2	A		
45WH59	14	C	R3	A		
45WH59	15	C	D	A		
45WH59	15	C	L1	P	SC/ SCST	P/ PO
45WH59	15	C	L2	P	SCST	PO
45WH59	15	C	L3	P	SCST	PO
45WH59	15	C	R1	P	SC	P
45WH59	15	C	R2	P	SC	P
45WH59	15	C	R3	P	SC/ SCHM	P
45WH59	16	C	D	A		
45WH59	16	C	L1	P	SCHM	PO
45WH59	16	C	L2	P	SCHM	PO
45WH59	16	C	L3	P	SCHM/ SC	PO
45WH59	16	C	R1	P	ST	P
45WH59	16	C	R2	P	ST/ SC	PO
45WH59	16	C	R3	P	SC	PO
45WH59	24	C	D	A		
45WH59	24	C	L1	A		
45WH59	24	C	L2	A		
45WH59	24	C	L3	A		
45WH59	24	C	R1	A		
45WH59	24	C	R2	A		
45WH59	24	C	R3	A		
45WH59	37	C	D	P	SC/ HM/ SC	P
45WH59	37	C	L1	A		
45WH59	37	C	L2	A		

45WH59	37	C	L3	A		
45WH59	37	C	R1	P	SC/HM/SC/HM	O/P/O/P/O
45WH59	37	C	R2	P	HM	O
45WH59	37	C	R3	A		
45WH59	44	C	D	A		
45WH59	44	C	L1	P	SC	P
45WH59	44	C	L2	P	SCST/ SCHMST/ HMST	PO/P/P
45WH59	44	C	L3	P	HMST	P
45WH59	44	C	R1	P	SC/ SCHM	P
45WH59	44	C	R2	P	SCHM/ SC/ SCHM	P
45WH59	44	C	R3	P	SCHM	P
45WH59	46	C	D	A		
45WH59	46	C	L1	P	SC	P
45WH59	46	C	L2	P	SC	P
45WH59	46	C	L3	P	SC	P
45WH59	46	C	R1	A		
45WH59	46	C	R2	A		
45WH59	46	C	R3	A		
45WH59	56	C	D	A		
45WH59	56	C	L1	P	SC	PO
45WH59	56	C	L2	P	SC	PO
45WH59	56	C	L3	P	SC/ ST	P
45WH59	56	C	R1	A		
45WH59	56	C	R2	P	SCHM	P
45WH59	56	C	R3	P	SCHM/ SCHMST	P
45WH59	57	C	D	A		
45WH59	57	C	L1	P	SCST	PO
45WH59	57	C	L2	P	SCST	P
45WH59	57	C	L3	P	SCHMST	P
45WH59	57	C	R1	A		
45WH59	57	C	R2	A		
45WH59	57	C	R3	A		
45WH59	59	C	D	A		
45WH59	59	C	L1	A		
45WH59	59	C	L2	A		
45WH59	59	C	L3	P	SCHM	P

45WH59	59	C	R1	P	SCHM	P
45WH59	59	C	R2	P	SCHM	P
45WH59	59	C	R3	P	SCHM	P
45WH59	67	C	D	A		
45WH59	67	C	L1	A		
45WH59	67	C	L2	P	SCHM	P
45WH59	67	C	L3	P	SCHM	P
45WH59	67	C	R1	A		
45WH59	67	C	R2	A		
45WH59	67	C	R3	A		
45WH59	74	C	D	A		
45WH59	74	C	L1	P	SC	P
45WH59	74	C	L2	A		
45WH59	74	C	L3	P	SC/SC	P
45WH59	74	C	R1	P	SCHM	P
45WH59	74	C	R2	P	SCHM	P
45WH59	74	C	R3	A		

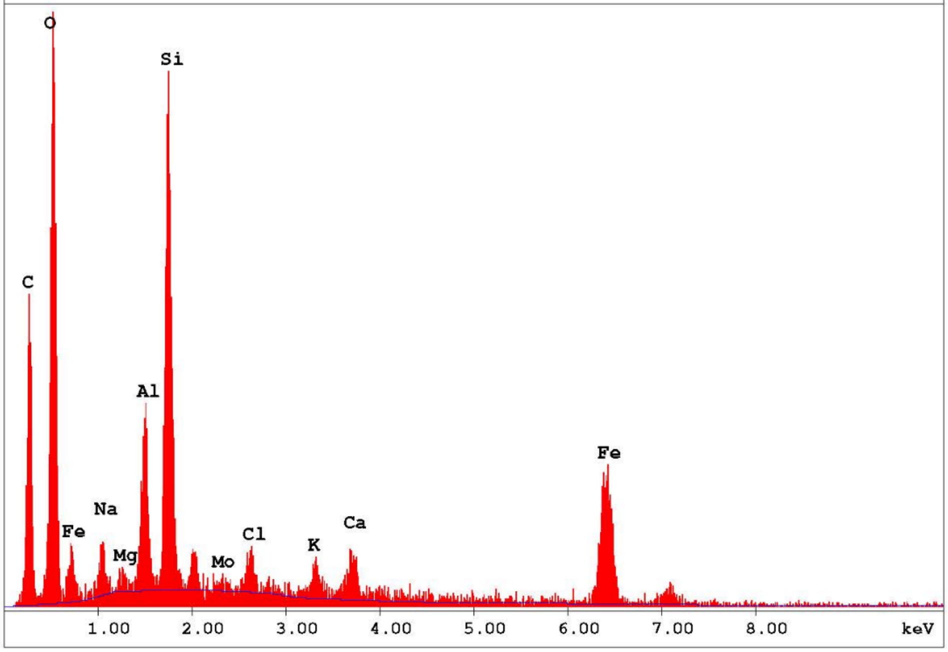
APPENDIX I: SEM-EDX RESULTS – 45WH55-760 AND 45WH59-176

c:\edax32\genesis\genspc.spc

Label:45WH55-760-tip

kV:15.0 Tilt:0.0 Take-off:45.0 Det Type:SUTW+ Res:128 Amp.T:102.4

FS : 430 Lsec : 20 20-Feb-2013 12:38:58

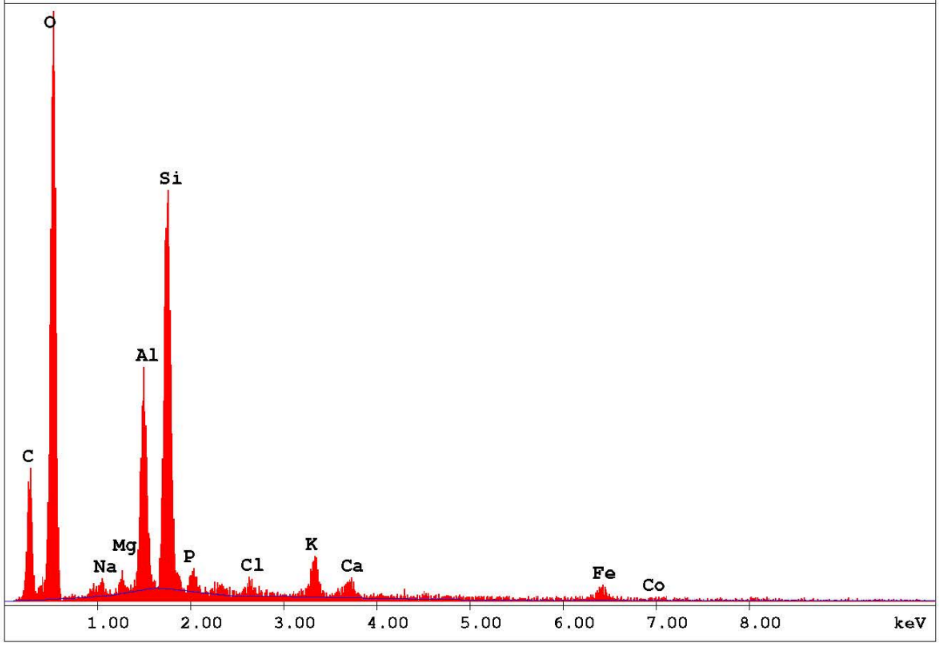


EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
O K	26.30	46.49	0.1210	1.0862	0.4230	1.0013
NaK	2.56	3.15	0.0105	1.0130	0.4030	1.0018
MgK	0.93	1.08	0.0052	1.0373	0.5356	1.0035
AlK	6.27	6.58	0.0421	1.0083	0.6624	1.0051
SiK	17.50	17.62	0.1340	1.0387	0.7361	1.0016
MoL	1.22	0.36	0.0090	0.8212	0.8991	1.0024
ClK	2.07	1.65	0.0178	0.9785	0.8715	1.0055
K K	2.26	1.63	0.0210	0.9812	0.9354	1.0126
CaK	3.67	2.59	0.0356	1.0026	0.9519	1.0136
FeK	37.21	18.85	0.3364	0.9068	0.9970	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
O K	105.05	0.60	2.19	175.08
NaK	10.75	2.95	8.49	3.64
MgK	5.20	4.40	16.09	1.18
AlK	40.45	4.75	3.91	8.52
SiK	116.15	5.40	2.17	21.51
MoL	3.15	5.25	26.23	0.60
ClK	11.45	5.20	9.13	2.20
K K	10.80	3.30	8.64	3.27
CaK	16.10	3.00	6.53	5.37
FeK	54.20	1.40	3.11	38.71

```
c:\edax32\genesis\genspc.spc
Label:45WH59-176-Dorsal
kV:15.0 Tilt:0.0 Take-off:43.5   Det Type:SUTW+ Res:128  Amp.T:102.4
FS : 855   Lsec : 20                                12-Mar-2013 15:40:32
```



```
EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element    Wt %    At %   K-Ratio     Z         A         F
   O K    45.95   62.29   0.2047   1.0407   0.4279   1.0005
   NaK     0.92    0.87   0.0048   0.9710   0.5299   1.0035
   MgK     0.85    0.76   0.0058   0.9944   0.6720   1.0069
   AlK    10.88    8.74   0.0828   0.9638   0.7829   1.0086
   SiK    24.64   19.03   0.1950   0.9886   0.7995   1.0015
   P K     1.56    1.09   0.0112   0.9540   0.7492   1.0017
   ClK     1.22    0.74   0.0100   0.9350   0.8754   1.0041
   K K     4.21    2.33   0.0373   0.9378   0.9414   1.0046
   CaK     2.39    1.29   0.0218   0.9578   0.9521   1.0027
   FeK     6.28    2.44   0.0541   0.8630   0.9982   1.0000
   CoK     1.11    0.41   0.0094   0.8436   1.0001   1.0000
  Total  100.00  100.00
```

```
c:\edax32\genesis\genspc.spc

Element  Net Inte.    Bkgd Inte.    Inte. Error       P/B
  O K     212.45         0.90          1.54        236.06
  NaK       5.85         2.75         12.88          2.13
  MgK       6.95         4.75         13.05          1.46
  AlK      95.55         6.80          2.44         14.05
  SiK     203.30         8.25          1.63         24.64
  P K      10.25         6.55         10.54          1.56
  ClK       7.75         4.00         11.45          1.94
  K K      23.15         3.30          5.27          7.02
  CaK      11.90         3.00          7.95          3.97
  FeK      10.50         0.70          7.35         15.00
  CoK       1.45         0.75         26.49          1.93
```

APPENDIX J: RESULTS OF CIEP ANALYSIS BY CSUBLAS (CSUBLAS 2014)

Protein Residue Analysis of 25 Quartz Microblades from Sites in the Salish Sea Region of Northwestern Washington

---

Prepared For:

Rachael Kannegaard
Western Washington University
Bellingham, Washington

Prepared By:

Laboratory of Archaeological Sciences
California State University
9001 Stockdale Highway
Bakersfield, CA 93311-1022
Director: Robert M. Yohe II, Ph.D., RPA
Associate Director: Carrie L. Stephens, B.A.

(LAS-351)

Introduction

The use of chemical and molecular biological techniques in the analysis of archaeological materials can provide significant new information for the interpretation of their use. The identification of organic residue from lithic and ceramics artifacts, coprolites and soils have provided archaeologists with specific data regarding prehistoric exploitation of animals and plants. Although ancient protein residues may not be preserved in their original form, linear epitopes are generally conserved which can be identified by immunological methods (Abbas et al. 1994).

Immunological methods have been used to identify plant and animal residues on flaked and groundstone lithic artifacts (Allen et al. 1995; Gerlach et al. 1996; Henrikson et al. 1998; Hyland et al. 1990; Kooyman et al. 1992; Newman 1990, 1995; Petraglia et al. 1996; Shanks et al.1999; Yohe et al. 1991) and in Chumash paint pigment (Scott et al. 1996). Plant remains on artifacts also been identified through chemical (opal phytoliths), and morphological (use-wear), studies (Hardy and Garufi 1998; Jahren et al. 1997, Sobolik 1996). Plant and animal residues on ceramic artifacts have been identified through the use of gas-liquid chromatography, high performance liquid chromatography and mass spectrometry (Bonfield and Heron 1995; Evershed et al. 1992*;* Evershed and Tuross, 1996; Heron et al. 1991, Patrick et al. 1985). Serological methods have been used to determine blood groups in skeletal and soft tissue remains (Heglar 1972; Lee et al. 1989) and in the detection of hemoglobin from 4500-year-old bones (Ascenzi et al. 1985). Human leukocyte antigen (HLA) and deoxyribonucleic acid (DNA) determinations made on human and animal skeletal and soft tissue remains have demonstrated genetic relationships and molecular evolutionary distances (Hänni et al. 1995; Hansen and Gurtler 1983; Lowenstein 1985, 1986; Pääbo 1985, 1986, 1989; Pääbo et al. 1989). Successful identification of residues on stone tools, dated between 35-60,000 B.P., has been made by DNA analysis (Hardy et al. 1997), while recently, residues on surgical implements from the American Civil War were identified by immunological and DNA analysis (Newman et al. 1998). A recent study demonstrated the viability of identifiable immunoglobulin G in 1.6 million-year-old fossil bones from Venta Micena, Spain, (Torres et al. 2002). Horse exploitation was identified by immunological analysis of residues retained on Clovis points dated to ca. 11,200 B.P. (Kooyman et al. 2001).

The use of forensic techniques in the investigation of archaeological materials is appropriate as both disciplines deal with residues that have undergone changes, either deliberate or natural. Criminals habitually endeavor to remove bloodstains by such means as laundering, scrubbing with bleach, etc. yet; such degraded samples are still identified by immunological methods (Lee and De Forest 1976; Milgrom and Campbell 1970; Shinomiya et al. 1978, among others). Similarly it has been shown that immunological methods can be successfully applied to ancient human cremations (Cattaneo et al. 1992). Forensic wildlife laboratories use immunological techniques in their investigation of hunting violations and illegal trade, often from contaminated evidence (Bartlett and Davidson 1992; Guglich et al. 1993; Mardini 1984; McClymont et al. 1982). Immunological methods are also used to test the purity of food products such as canned luncheon meat and sausage, products which have undergone considerable degradation (Ashoor et al. 1988; Berger et al. 1988; King 1984). Thus the age and degradation of protein does not preclude detection (Gaensslen 1983:225).

Materials and Methods

The method of analysis used in this study of archaeological residues is cross-over immunoelectrophoresis (CIEP). Prior to the introduction of DNA fingerprinting this test was used by forensic laboratories to identify trace residues from crime scenes. Minor adaptations to the original method were made following procedures used by the Royal Canadian Mounted Police Serology Laboratory, Ottawa (1983). The solution used to remove possible residues is five percent ammonium hydroxide which is the most effective extractant for old and denatured proteins without interfering with subsequent testing (Dorrill and Whitehead 1979; Kind and Cleevely 1969). Artifacts are placed in shallow plastic dishes and 0.5 ml of five percent ammonia solution applied directly to each. Initial disaggregation is carried out by floating the dish and contents in an ultrasonic cleaning bath for five minutes. Extraction is continued by placing the dish and contents on a rotating mixer for thirty minutes. For large ground stone items, such as metates, stone bowls, etc., the ammonium hydroxide is applied directly to the worked surface, agitated periodically with a sterile orangewood stick, and allowed to sit for one half hour. The resulting solution is drawn off, placed in a numbered, sterile plastic vial and stored at -20ºC prior to testing. In the case of soil samples, one gram is placed in a vial and 0.5 ml of 1 M Tris buffer solution ($H_2NC[CH_2OH]_3$) is used instead of ammonium hydroxide. The vial is placed in a rotating mixer overnight. The resulting solution is drawn off, placed in a numbered, vial and stored at -20ºC prior to testing.

A series of paired wells is punched into an agarose gel. Approximately 2 µl. of antiserum is placed into one well and the same amount of the unknown sample extract is placed in the other. An electric current is then passed through the gel. The antiserum and unknown sample migrate through the gel and come into contact. If there is protein in the unknown which corresponds with the antiserum, an antigen-antibody reaction occurs and the protein precipitates out in a specific pattern. The precipitant is detected when the gel is pressed, dried and stained. Control positives are run simultaneously with all the unknown samples. Sterile equipment and techniques are used throughout the analysis.

The Samples

Fifteen «Number_of_Artifacts»«Types_of_artifacts_tested»artifacts were submitted for immunological analysis by Rachael Kannegaard of Western Washington University«Company_Name»«Client_City_»«Client_State». Residue was removed from the artifacts as discussed above. The residue was tested against a suite of plant and animal antisera (Table 1). Animal antisera provided by Cappel Research and Lampire Biomedical, and plant antisera produced at the University of Calgary, provide family level identification only. The relationship of antisera to some of the possible species identified is shown in Table 2.

Results

Three«Number_of_positive_hits» positive reactions were registered for the quartz microblades. Artifact number 760 was tested in two separate locations, the tip and base, and both resulted in positive reactions to human. The distal region of the blade registered a significantly stronger reaction than that of the base. A second artifact, number 119, registered a positive reaction for rabbit. No other positive reactions were observed (Table 3). Unless otherwise noted, any soil samples submitted were negative. The absence of identifiable proteins on an artifact may be due to poor preservation of protein, insufficient protein, or that they were not in contact with any of the organisms included in the available antisera.

TABLE 1: ANTISERA USED IN ANALYSIS

Animal Antiserum	**Source**	**Plant Antiserum**	**Source**
Bovine	“	Asteraceae	University of Calgary
Porcine	Cappel Research	Camas	“
Feline	“	Capparaceae	“
Phasianinae	“	Chenopodiaceae	“
Cervinae	“	Cupressaceae	“
Cavinnae	“	Lomatium	“
Caprinae	“	Malvaceae	“
Hominini	Cappel Research	Amaranthaceae	“
Leporidae	“	Kelp	Cedarlane Laboratories
Murinae	“	Pinaceae	University of Calgary
Triopsidae	“	Cedar	“
Salmoninae	Cedarlane Laboratories		

TABLE 2: POSSIBLE SPECIES IDENTIFIED

Antiserum to:	Reacts with:
Alligator	alligator, crocodile
Bear	black, grizzly, etc
Bovine	bison, cow, musk ox
Camel	all camelids (New & Old world)
Cat	bobcat, cougar, lynx, etc.
Chicken	quail, grouse, & other gallinaceous fowl
Deer	deer, elk, moose
Elephantidae	elephant, mammoth
Guinea-pig	beaver, guinea-pig, porcupine, squirrel
Horse	horse, donkey, kiang, etc.
Human	human
Rabbit	rabbit, hare, pika
Rat	all rat & mouse species
Sheep	bighorn & other sheep
Triops	triops
Trout	trout and salmon species
Agave	yucca, agave
Amaranthaceae	amaranth, pigweed, *quelite*, etc.
Asteraceae	rabbitbrush, sagebrush, sunflower, thistle
Camas	camas, wild hyacinth
Capparaceae	beeplant, bladderpod, stinkweed, etc.
Chenopodiaceae	goosefoot, greasewood, pickleweed, saltbush, etc
Cupressaceae	cedar, cypress, juniper
Lessoniaceae	kelp, possibly algae
Lomatium	*Lomatium sp.*
Malvaceae	mallows
Mesquite	mesquite, palo verde, other legumes
Portulacaceae	bitterroot
Pinaceae	fir, hemlock, pine, spruce

TABLE 3A: RESULTS

Las #	Site #	FS or Cat. #	Description	Results
1	45WH1	179	microblade	Negative
2	45WH1	119	microblade	Rabbit
3	45WH55	1147	fragment	Negative
4	45WH55	1565	microblade	Negative
5	45WH55	1817	microblade	Negative
6	45WH55	707	microblade	Negative
7a	45WH55	760	tip of blade	Human
8	45WH59	9	micro/black fragment	Negative
9	45WH59	15	microblade	Negative
10	45WH59	16	microblade	Negative
11	45WH59	31	quartz fragment	Negative
12	45WH59	36	microblade fragment	Negative
13	45WH59	37	microblade fragment	Negative
14	45SK46	1163	microblade	Negative
15	45SK46	1166	fragment	Negative
7b	45WH55	760	base of blade	Human

TABLE 3B: SECOND ROUND TESTING RESULTS

Las #	Site #	FS or Cat #	Description	Results
16	45SK46	1172	Microblade	Negative
17	Unknown	1171	Microblade	Deer, Human
18	45WH55	507	Microblade	Negative
19	45WH1	54	Microblade	Human
20	45SK46	1168	Microblade	Negative
21	45SK46	1165	Microblade	Negative
22	45SK46	1164	Microblade	Negative
23	45SK46	407	Microblade	Salmon
24	45WH55	612	Microblade	Negative
25	45WH17	1344	Microblade	Negative

References Cited

Abbas, A. K., A. H. Lichtman, and J. S. Pober
1994 *Cellular and Molecular Immunology.* W. B. Saunders, Philadelphia.

Allen, J., M. E. Newman, M. Riford, and G. H. Archer
1995 Blood and Plant Residues on Hawaiian Stone Tools from Two Archaeological Sites in Upland Kane`one, Ko`ola Pogo District, O`ahu Island. *Asian Perspectives* 34(2):283-302.

Ascenzi, A., M. Brunori, G. Citro, and R. Zito
1985 Immunological Detection of Hemoglobin in Bones of Ancient Roman Times and of Iron and Eneolithic Ages. *Proceedings National Academy of Sciences USA* 82:7170-7172.

Ashoor, S. H., W. C. Monte, and P.G. Stiles
1988 Liquid Chromatographic Identification of Meats. *J. Assoc. Off. Anal. Chem.* 71:397-403.

Bartlett, S. E., and W. S. Davidson
1992 FINS (Forensically Informative Nucleotide Sequencing): A Procedure for Identifying the Animal Origin of Biological Specimens. *Biotechniques* 12:408-411.

Berger, R. G., R. P. Mageau, B. Schwab, and R.W. Johnson
1988 Detection of Poultry and Pork in Cooked and Canned Meats by Enzyme-linked Immunoabsorbent Assays. *J. Assoc. Off. Anal. Chem* 71:406-409.

Bonfield, K., and C. Heron
1995 The Identification of Plant Waxes in Neolithic Pottery: Evidence for "Invisible" Foods. Paper presented at Archaeological Sciences Meeting, 1995, University of Liverpool, U.K.

Cattaneo, C., K. Gelsthorpe, P. Phillips, and R. J. Cecal
1992 Reliable Identification of Human Albumin in Ancient Bone using ELIZA and Monoclonal Antibodies. *American Journal of Physical Anthropology* 87:365-372.

Dorrill, M., and P. H. Whitehead
1979 The Species Identification of Very Old Human Bloodstains. *Forensic Science International* 13:111-116.

Evershed, R. P., C. Heron, and L. J. Goad
1992 The Survival of Food Residues: New Methods of Analysis, Interpretation and Application. *Proceedings of the British Academy* 77:187-208.

Evershed, R. P., and N. Tuross
1996 Proteinaceous Material from Potsherds and Associated Soils. *Journal of Archaeological Science* 23:429-436.

Gaensslen, R. E.
1983 *Sourcebook in Forensic Serology, Immunology, and Biochemistry*. U. S. Department of Justice, Washington, D.C.

Gerlach, S. C., M. E. Newman, E. J. Knell, and E. S. Hall
1996 Blood Protein Residues on Lithic Artifacts from Two Archaeological Sites in the De Long Mountains, Northwestern Alaska. *Arctic* 49(1):1-10.

Guglich, E. A., P. J. Wilson, and B. N. White
1993 Application of DNA Fingerprinting to Enforcement of Hunting Regulations in Ontario. *Journal of Forensic Science* 38:48-59.

Hänni, C., A. Begue, V. Laudet, D. Stéhelin, T. Brousseau, and P. Amouyel
1995 Molecular Typing of Neolithic Human Bones. *Journal of Archaeological Science* 22 (5):649-658.

Hansen, H. E., and H. Gurtler
1983 HLA Types of Mummified Eskimo Bodies from the 15th Century. *American Journal of Physical Anthropology* 61:447-452.

Hardy, B. L., and T. Garufi
1998 Identification of Woodworking on Stone Tools through Residue and Use-Wear Analyses: Experimental Results. *Journal of Archaeological Science* 25:177-184.

Hardy, B. L., R. A. Raff, and V. Raman
1997 Recovery of Mammalian DNA from Middle Paleolithic Stone Tools. *Journal of Archaeological Science* 24:601-611.

Heglar, R.
1972 Paleoserology Techniques Applied to Skeletal Identification. *Journal of Forensic Sciences* 16:358-363.

Henrikson, L. S., R. M. Yohe II, M. E. Newman, and M. Druss
1998 Freshwater Crustaceans as an Aboriginal Food Resource in the Northern Great Basin. *Journal of California and Great Basin Anthropology* 20:72-87.

Heron, C. L., R. P. Evershed, L. J. Goad, and V. Denham
1991 New Approaches to the Analysis of Organic Residues from Archaeological Remains. In *Archaeological Sciences 1989*, edited by P. Budd, B. Chapman, R. Janaway and B. Ottaway, pp.332-339. Oxbow Monograph 9. Oxford.

Hyland, D. C., J. M. Tersak, J. M. Adovasio, and M. I. Siegel
1990 Identification of the Species of Origin of Residual Blood on Lithic Material. *American Antiquity* 55:104-112.

Jahren, A. H., N. Toth, K. Schick, J. D. Clark, and R. G. Amundsen
1997 Determining Stone Tool Use: Chemical and Morphological Analyses of Residues on Experimentally Manufactured Stone Tools. *Journal of Archaeological Science* 24:245-250.

Kind, S. S., and R. M. Cleevely
1969 The Use of Ammoniacal Bloodstain Extracts in ABO Groupings. *Journal of Forensic Sciences* 15:131- 134.

King, N. L.
1984 Species Identification of Cooked Meats by Enzyme-Staining of Isoelectricfocusing Gels. *Meat Science* 11:59-72.

Kooyman, B., M. E. Newman, and H. Ceri
1992 Verifying the Reliability of Blood Residue Analysis on Archaeological Tools. *Journal of Archaeological Science* 19 (3):265-269.

Kooyman, B., M. E. Newman, C. Cluney, M. Lobb, S. Tolman, P. McNeil, and L. V. Hills
2001 Identification of Horse Exploitation by Clovis Hunters Based on Protein Analysis. *American Antiquity* 66:686-691.

Lee, H. C., and P. R. DeForest
1976 A Precipitin-Inhibition Test on Denatured Bloodstains for the Determination of Human Origin. *Journal of Forensic Sciences* 21:804-809.

Lee. H. C., R. E. Gaensslen, H. W. Carver, E. M. Pagliaro, and J. Carroll-Reho.
1989 ABH Typing in Bone Tissue. *Journal of Forensic Sciences* 34(1):7-14.

Lowenstein, J. M.
1985 Molecular Approaches to the Identification of Species. *American Scientist* 73:541-547.

1986 Evolutionary Applications of Radioimmunoassay. *American Biotechnology Laboratory* 4(6):12-15.

Mardini, A.
1984 Species Identification of Selected Mammals by Agarose Gel Electrophoresis. *Wildlife Society Bulletin* 12(3):249-251.

McClymont, R. A., M. Fenton, and J. R. Thompson

1982 Identification of Cervid Tissues and Hybridization by Serum Albumin. *Journal of Wildlife Management* 46(2):540-544.

Milgrom, F., and W. A. Campbell
1970 Identification of Species Origin of Tissues Found in a Sewer. *Journal of Forensic Sciences* 15(1): 78-85.

Newman, M. E.
1990 The Hidden Evidence from Hidden Cave, Nevada. Unpublished Ph.D. dissertation, Department of Anthropology, University of Toronto.

1995 Organic Residue Analysis of Lithic Artifacts from Le Trou Magrite. In *Le Trou Magrite. Fouilles* 1991-1992, edited by M. Otte and L.G. Straus. Liège, E.R.A.U.L. 69:189-194.

Newman, M. E., G. Byrne, H. Ceri, and P. J. Bridge
1999 Immunological and DNA Analysis of Blood Residues from a Surgeon's Kit used in the American Civil War. *Journal of Archaeological Science* 25:553-557.

Pääbo, S.
1985 Molecular Cloning of Ancient Egyptian Mummy DNA. *Nature* 314:644-645.

1986 Molecular Genetic Investigations of Ancient Human Remains. *Cold Spring Harbor Symposia on Quantitative Biology*, 11:441-446.

1989 Ancient DNA: Extraction, Characterization, Molecular Cloning, and Enzymatic Amplification. *Proceedings National Academy of Science USA* 86:1939-1943.

Pääbo, S., R. G. Higuchi, and A. C. Wilson
1989 Ancient DNA and the Polymerase Chain Reaction. *The Journal of Biological Chemistry* 264:269.

Patrick, M., A. J. Koning, and A.B. Smith
1985 Gas-liquid Chromatographic Analysis in Food Residues from Ceramics Found in the Southwestern Cape. *Archaeometry* 27:231-236.

Petraglia, M., D. Knepper, P. Glumac, M. E. Newman, and C. Sussman
1996 Immunological and Microwear Analysis of Chipped-stone Artifacts from Piedmont Contexts. *American Antiquity* 61:127-135.

Royal Canadian Mounted Police
1983 Methods Manual, Serology Section. Ottawa, Ontario.

Scott, D. A., M. E. Newman, M. Schilling, M. Derrick, and H. P. Khanjian

1996 Blood as a Binding Medium in a Chumash Indian Pigment Cake. *Archaeometry* 38:103-112.

Shanks, O. C., M. Kornfeld, and D. D. Hawk
1999 Protein Analysis of Bugas-Holding Tools: New Trends in Immunological Studies. *Journal of Archaeological Science* 26:1183-1191.

Shinomiya, T., M. Muller, P. H. Muller, and R. Lesage
1978 Apport de l'immunoelectrophorese pour l'expertise des taches de sang en medicine legale. *Forensic Science International* 12:157-163.

Sobolik, K. D.
1996 Lithic Organic Residue Analysis: An Example from the Southwestern Archaic. *Journal of Field Archaeology* 23:461-469.

Torres, J. M., C. Borja, and E. G. Olivares
2002 Immunoglobulin G in 1.6 Million-year-old Fossil Bones from Venta Micena (Granada, Spain). *Journal of Archaeological Science* 20: 167-175.

Yohe, R. M. II, M. E. Newman, and J. S. Schneider
1991 Immunological Identification of Small-Mammal Proteins on Aboriginal Milling Equipment. *American Antiquity* 56: 659-666.