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EXAMINING PAST TREATMENTS OF CEDAR AND SPRUCE WATERLOGGED BASKETRY FROM THE NORTHWEST COAST

DANA K. SENGE AND ELLEN CARRLEE

ABSTRACT

Basketry artifacts fabricated from limb wood, spruce and cedar root, and the inner bark of yellow and western red cedar have been found in water-saturated archaeological sites in the Pacific Northwest since the mid-20th century. These artifacts range in age from a few centuries to more than five thousand years old. While these materials retain their overall physical structure due to burial in an anoxic environment they are degraded on the cellular level. Experiments and treatments performed by archaeologists and conservators over the past 40 years have attempted to stabilize these degraded structures to minimize splitting, crumbing, and distortion of the woven structures as they dried. Early treatments were guided by research done for preserving waterlogged ship timbers from the Vasa warship in Sweden and boats from Lake George, New York. Recent research has shown that the size of typical basketry elements limits the use of the PEGcon computer program developed at the Canadian Conservation Institute to determine the level of cellular degradation and that the cellular structure of some basketry material, such as inner bark, differs enough from trunk wood to require a variation in treatment. Recommendations for the best conservation methods for these materials is still under examination as conservators in Alaska, British Columbia, the Pacific Northwest, and scientists at the Canadian Conservation Institute continue to study the woody elements of these artifacts and the effects of treatment products. This paper summarizes and compares past treatments and the current condition of basketry from multiple wet sites on the Northwest Coast and discusses some of the current avenues under research.

1. INTRODUCTION

Water saturated archaeological sites, or wet sites, became part of the archaeological excavations in the Pacific Northwest in the late 1950s when the Biderbost Site in Washington State was excavated by the Washington Archaeology Society (Nordquist 1976) and Dr. David Rice (Phillips and Deep 2008). Artifacts fabricated from wood and plant based materials ranging from 200-5000 years old have been recovered from wet sites around the northwest coast region of the United States and Canada and have provided a window into the culture, tools, techniques and life of the Native/Aboriginal communities in the region. Materials recovered from these sites range from baskets and mats, clothing, house planks, spindle whorls and looms, tools, carvings, and detritus from carving and processing materials.

These organic artifacts, fabricated from wood, limb, inner bark and root, are preserved in an anoxic environment created by the continuous presence of water. In this environment deterioration of the wood structure is slowed but not stopped. The water-soluble molecules, such as cellulose, are slowly removed from the structure either through slow bacterial removal or slow hydrolysis and are replaced with water molecules. When recovered from the burial environment the organic material of the object may look whole, but quickly proves delicate when handled. Individual segments of root or inner bark may be so deteriorated they can easily be mushed apart by fingertips or split into thinner components. Woven or twined artifact and segments are stronger despite the degraded nature of the individual elements, the three dimensional macro structure itself acting to hold or restrain the materials from complete deterioration.

If allowed to air dry, these wood based materials will split, check, curl and distort as observed in materials both thick and thin in controlled slow air-drying tests (Erling 1990; Senge 2009) as well as air drying in an uncontrolled environment.

For at least fifty years conservators and archaeologists in the Northwest Coast region have been testing and implementing techniques to reduce the shrinkage and physical distortion of basketry. While similar to larger wood artifacts the fine elements of basketry materials have proven to require additional considerations in treatment solutions. Much has been researched and published about the preservation of wood from underwater or water-saturated burial environments, therefore the remainder of this publication will focus on history of treatment of basketry materials, an area that has not been discussed to as great an extent. For the purposes of this article, basketry materials in the Pacific Northwest are defined as artifacts fabricated from twined or woven elements and take the form of a variety of artifacts including: hats, baskets, mats, nets, cordage, and clothing. The materials themselves range from splints of limb, withe (narrow diameter 'twig'), root and inner bark (phloem). The width of these materials used in basketry ranges regardless of material type. Inner bark materials range from 1" wide strands used in matting to 1/4" wide or narrower used many types of baskets. Limb, twig and root also range from approximately 1/4" wide splints, most often used as warp material in open weave baskets, to 1/16" inch or narrower strands, most commonly used as weft material in twined basketry.

2. BACKGROUND

In 1976 the proceedings of two conferences focusing on the preservation of waterlogged artifacts were published: *The Excavation of Water Saturated Archaeological Sites (Wet Sites) on the Northwest Coast of North America* (Croes 1976) and *Pacific Northwest Wet Site Wood Conservation Conference* (Grosso 1976b). While the papers published in these proceedings covered a range of organic materials, many discuss the treatments tested, immediate results and conclusions regarding the treatments of basketry material. These papers provide some of the only published treatment documentation for waterlogged basketry collections on the Northwest Coast. In general they describe the transition of treating waterlogged materials with diluted vinyl copolymer adhesives to working with polyethylene glycol as an impregnant (Borden 1976; Croes 1976; Daughtery 1976; Gleeson and Grosso 1976; Grosso1976b; Hobler 1976; Munsell 1976; Norquist 1976; Onat 1976; Simonsen 1976; Sprague 1976). This transition was inspired by publications in Europe and North America on waterlogged timbers from the Vasa and dugout canoes in Lake George, NY (Barkman 1962; Seborg and Inverity 1962).

Throughout the research represented in the papers published in 1976 one reads the dissatisfaction archaeologists and conservators had with treatment methods. This continues into the 1980s and 90s as people continued to research the use of the most popular impregnant, polyethylene glycol. Jo Ann Erling, a contract conservator working in Victoria, British Columbia, tested a wide range of concentrations of polyethylene glycol and impregnation time when considering the treatments of materials from Water Hazard (DgRs30). While this testing remains unpublished, her research and images remain with the collection housed at the Laboratory of Archaeology at the University of British Columbia.

In the early 1990s, Vincent and Deborah Cooke worked with conservators from the Canadian Conservation Institute (CCI) to examine re-treatment options of basketry materials from Ozette currently housed at the Makah Cultural and Research Center in Neah Bay, Washington. They selected three basketry fragments to include in their testing, removed the impregnate, freeze dried the fragments and tested consolidation with Polyox and Parylene. They felt the consolidants improved visibility of woven design and the artifacts maintained stability after re-treatment (Cooke and Cooke 1994). When examined in 2009 the samples show some sheen from the consolidant materials but appeared stable for handling, exhibit and research after fifteen years in their relatively stable storage environment at the Makah Cultural and Research Center.

In 1996 and 1998 conservators and scientists from the CCI presented and published their work with polyethylene glycol (PEG) treatments of waterlogged basketry materials and a study into the penetration of PEG into the inner bark of western red cedar (Grant 1996; Bilz 1998). In the treatments described in the 1996 article, 'Conservation of Waterlogged Cedar Basketry and Cordage', the basketry material and cordage treated with PEG 400 was stabilized but somewhat brittle. Some of the pieces required additional consolidation with Parylene to be stable for travel and exhibition. The research described in the 1998 article, 'Treating Waterlogged Basketry: A Study of Polyethylene Glycol Penetration Into the Inner Bark of Western Red Cedar', shows that the cellular structure of cedar inner bark is different enough from the wood that treating baskets with the same concentration and molecular weight of PEG as waterlogged cedar wood may not be the best course of action for stabilizing these materials. The research was performed on processed fresh inner bark. The results of these examinations were used to extrapolate how polyethylene glycol would enter the degraded materials from an archaeological wet site.

The testing performed in the 1970s, 80s and 90s has been very helpful in understanding the movement of different molecular weights of polyethylene glycol into the cellular structure and the challenges of working with basketry materials. In 2006, the authors began to summarize the historic background of past testing and treatments in an effort to make informed choices for the treatment of waterlogged basketry materials, and build on the experimentation published in the 1998 article from Bilz, Grant and Gregory. The following sections summarize these past treatments of basketry materials and how they have aged through visual and physical characteristics.

3. HISTORIC TREATMENTS

Many of the historic and current treatments of basketry face the challenge of removing water from water-saturated cells without also losing the structural support the water provides in the degraded material. The treatment must also counteract the strong forces caused by capillary action and the high surface tension of water when it evaporates. Treatments have revolved around variations of slowly drying the materials or impregnating the structure prior to drying to replace lost molecules, bulk the voids, and control shrinkage or deformation of the elements of the artifacts. Additional treatment methods have included consolidation of loose, dry, brittle material after the drying or impregnation /drying treatments.

Early treatment materials and techniques included coating the surface with vinyl copolymer adhesives such as Elmer's or Plyamul[1] diluted in water, slow drying with Firewater and Houston #3 [2] drying between two layers of glass and impregnation with polyethylene glycol at various molecular weights in various concentrations and for various lengths of time. More recent published consolidation tests have focused on the use of Parylene and Polyox recognizing that stability had not been fully achieved in the earlier treatments. The physical characteristics of the treated artifacts ranges from tan-colored, lightweight, brittle and dry on one extreme to dark brown, heavy, waxy, flexible, and slightly moist to the touch on the other extreme.

The treatments described in this paper were gathered from existing treatment records from 27 of 37 recognized water saturated terrestrial sites in Oregon, Washington State, British Columbia and Alaska that contained basketry materials. While anecdotal information about possible treatment techniques used have been relayed to the authors, distant memories can be mistaken therefore following summaries depend solely on the written record from both published sources and collection treatment records.

3.1 AIR OR SOLVENT DRYING TREATMENTS

In general the air and solvent dried materials are light, brittle, shrunken or misshapen (unless dried between two plates of glass), regardless of age and level of deterioration (fig. 1). The basket recovered from the Castle Hill site is Alaska is an exception to this finding (fig. 2). The records for this piece describe it as not fully waterlogged when found. The basket was placed on a sheet of Plexiglas in a refrigerator. After several years of debating treatment options, the piece was re-examined and discovered to be dry with basketry elements remaining flexible and was considered stable when handled. This result was attributed to the basket being only slightly damp and not water saturated when excavated. The condition of the basket at excavation was only minimally deteriorated. Sufficient air drying likely occurred within the first year.

Fig. 1. Air-dried fragment from Spruce Root Basket, Baranov Museum (Photograph by Dana Senge)

Fig. 2. Castle Hill basket, TD 99-7, slowly air-dried without impregnation with polyethylene glycol (Courtesy of Alaska State Museum)

3.2 COATING WITH ADHESIVE TREATMENTS

Several authors have published anecdotal information regarding treatment with a white glue, either vinyl acetate copolymer (VAC) or poly vinyl acetate adhesive (PVA). These include the archaeological sites of Ozette (Daugherty 1976), Hoko River (Croes 1976) and Biderbost (Nordquist 1976). Of these three collections only artifacts from Biderbost collection were found to exhibit this type of treatment. A few artifacts from Ozette and Hoko River were treated with a PVA adhesive before treatment solutions shifted to the use of polyethylene glycol (Daugherty 1976; Croes 1976). However no evidence of basketry with the characteristic sheen of white glue treatment or treatment records citing artifact numbers have been found by the authors in either the Ozette or Hoko Complex collections.

All of the materials from the Biderbost site were treated with 25% Plyamul adhesive #9153 in Firewater, a heavy detergent manufactured by the Firewater Company of Los Altos. These were examined in 2009 and found to be rigid and firm with excess adhesive dried on the surfaces. The treatment was considered successful at the time since it minimized shrinkage and splitting of the material, however a contemporary assessment is that the treatment is somewhat crude with pools of adhesive on the basketry elements confusing the visual understanding of the material. In addition, the Plyamul adhesive has proved slightly soluble in ethanol and not very reversible. The conservation material contaminates any samples taken from the treated artifacts, impacting potential instrumental analysis in research. The rigidity of the basketry materials observed might be due in part to the conservation materials and in part to the physical characteristics of original elements, which were thick sections of bark and root. Cross sections cut from the inner bark samples of Biderbost basketry were brittle and crumbled during slicing; the root material was hard but maintained its structure during sectioning with a razor. Examination of a transverse section of the root material viewed under ultraviolet irradiation shows the adhesive along the edge and filling the lumina near the surface (fig. 4).

Fig. 3. Basketry fragment from Biderbost collection, 45SN100-335
(Courtesy of the Thomas Burke Memorial Washington State Museum)

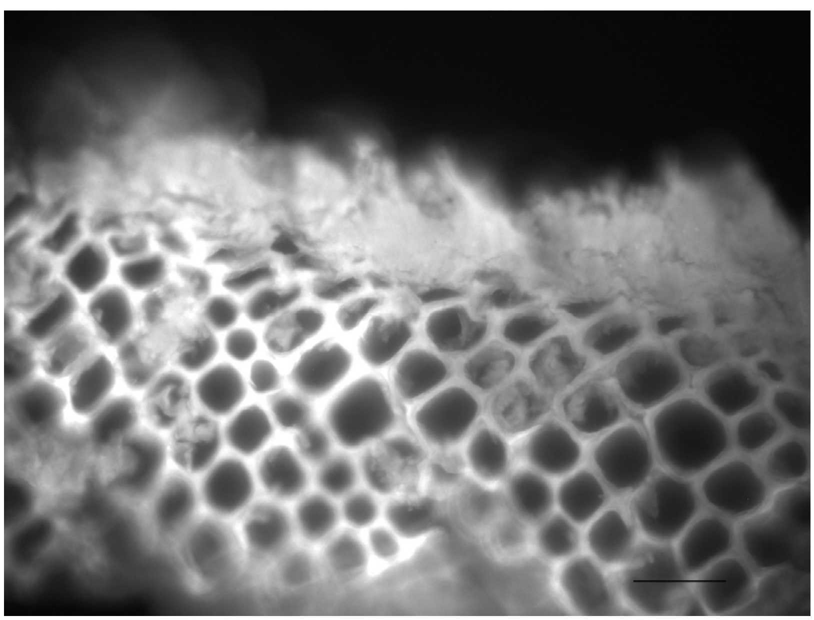

Fig. 4. Transverse view from sample of root from Biderbost collection (45SN100-330a) at the Thomas Burke Memorial Washington State Museum, viewed with Olympus BX-51 using ultraviolet irradiation to view fluorescence of adhesive along top edge. Lignin in cellular structure in exhibiting natural fluorescence. Bar is 10m. (Photograph by Dana Senge)

3.3 POLYETHYLENE GLYCOL TREATMENTS

During the initial seasons at Ozette in 1966 and 1967 the archaeologists realized that the white glue adhesive treatment was not an ideal solution. The effects of the adhesive were described as producing a stiff whitish looking basket (Daugherty and Croes 1976). This spurred the research of Gerald Grosso into the possibilities of working with polyethylene glycol to impregnate the structure and replace water molecules that would leave during the drying process. Over the next several years he and Richard Daugherty looked at treatments developed in U.S. and Europe for waterlogged wood artifacts including the Vasa treatments published by Lars Barkman (Barkman 1962) and the treatments of waterlogged boats from Lake George, NY published by Seborg and Inverarity (Seborg and Inverarity 1962). From this research they tested a range molecular weights and concentrations to develop a method of volume processing these materials in the remote worksite of Cape Alva in order to safely move the artifacts from the site to a workspace (Grosso 1976a).

Around the same period other archaeologists in the region were inspired by the publications of Barkman and Seborg and also developed methods of working with polyethylene glycol. As a result during the 1970s many basketry artifacts in the northwest coast region were treated with a range of treatments using polyethylene glycol (PEG) as a consolidant or impregnant. Treatments developed during this time period varied by impregnation bath time, molecular weight of polyethylene glycol and concentration of the PEG in water. These variables in treatment, along with variables of material types and level of degradation, resulted in a wide range of final results from tan-colored/lightweight/dry/brittle at one extreme to dark-colored/heavy/waxy/flexible materials at the other.

The most significant variable found in past basketry treatments in this region is duration of impregnation. Artifacts with short treatment times (1/2 day – 2 weeks) in medium to high molecular weight (1000-4000) polyethylene glycol (PEG) are generally dry in appearance and delicate to handle. The PEG appears to have aided in slow drying the artifacts and minimizing shrinkage and distortion, but did not truly penetrate the inner bark and root cellular structure leaving the artifacts delicate to handle for exhibit and research. This is observed when examining a transverse section of material from the Conway wet site (fig. 5).

These objects were treated by soaking in ethyl alcohol for 2 days and then placing in an impregnation baths of 33% PEG 1000 in water for 2-4 days, upon removal from the bath these artifacts were allowed to dry from 1-2 weeks. The section sample was stained with cobalt thiocyanate (Bilz 1998) and examined at 400x magnification with an Olympus BX-51 microscope under ultraviolet irradiation. The stain bonds to any PEG in the structure and quenches the natural fluorescence of the lignin in the structure. Figure 5 shows that there was little to no PEG present in the structure for the stain to bond with and the auto fluorescence of the lignin is clearly observed.

The main treatment method developed for the materials from Ozette was a four week impregnation period with 50% PEG 1500. PEG 1500 was renamed in the mid 1970s to PEG 540 Blend, which is believed to be the same 540 blend that exists today: 41% PEG 300 and 59% PEG 1450. These materials are often dark brown/black, sometimes waxy in appearance and are slightly moist to the touch. Transverse sections cut from a sample western red cedar inner bark from the Ozette material were pliable and PEG oozed from the structure when placed in a warm, humid environment. The inner bark material from Ozette disintegrated during the cobalt thiocyanate staining process, the material was too delicate to examine the level of impregnation of PEG into the cellular structure.

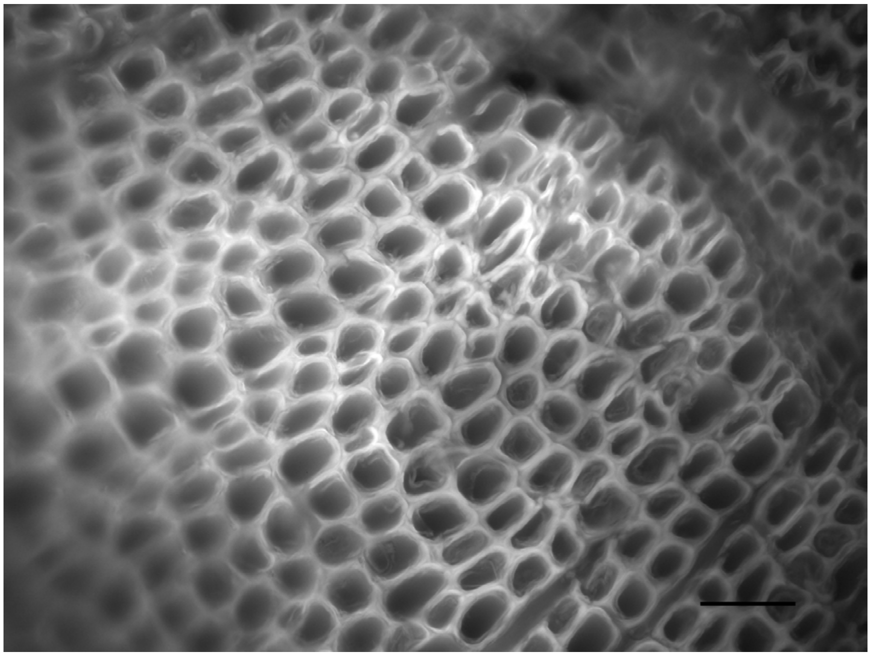

Fig. 5. Transverse from sample of root from Conway collection (45SK59b-72) at the Thomas Burke Memorial Washington State Museum, viewed with Olympus BX-51 using ultraviolet irradiation. Lignin in cellular structure in exhibiting natural fluorescence. Bar is 10m. (Photograph by Dana Senge)

Fig. 6. Basket 71/V/68 from the Ozette site
(Photograph by Janine Bowechop, courtesy of the Makah Cultural and Research Center)

In the mid-90s Tara Grant and Malcom Bilz at CCI began testing treatment solutions and found a mix of lower concentration (20%) and lower molecular weight (400) and long immersions that provided a step towards a more desirable treatment outcome for many materials from the Scowlitz site (DHR1-16W). Several pieces were treated with these concentrations and time periods, frozen and freeze-dried, then consolidated with Parylene. These pieces are light in color and appear fairly stable overall, the basketry elements were flexible and the surface spongy to the touch. However, the need to consolidate with Parylene (itself an experimental, last-resort treatment that does not allow easy re-treatability) suggests the PEG protocol alone was not enough for these materials.

The South Baranof Island Basket #1 from the Alaska State Museum was treated in 1994 with 20% PEG 400 and 5% PEG 4000 over the course of 6 months, upon the recommendations of Tara Grant at CCI. Upon examination in 2009 the basketry fragments have a very natural-looking, pleasing appearance with no observable shrinkage or distortion, and the individual elements appear to have maintained some of their flexibility. However, the material is also very spongy to the touch, sheds fibers, and is too delicate for travel or exhibition.

A variation of this technique developed at CCI is currently in use at South Puget Sound Community College. The lab within the archaeology department has been treating materials for an active site at Mud Bay (Qwu? Gwes[3]) in Washington State for several years, as well as basketry material found at Sunken Village in Oregon in 2006 and 2007. The general treatment process in practice in the lab is to place basketry materials in a bath of 50% PEG 400 for 4 months. The authors have not had an opportunity to observe or examine these materials treated through this specific variation of the polyethylene glycol impregnation treatment.

3.4 OTHER TREATMENT METHODS

Wet storage in a cold environment may have been considered for a while by conservation departments in museums in southern British Columbia (Alten 2010). While no records exist regarding actual use of this method at the Royal British Columbia Museum Conservation Lab or the University of British Columbia Museum of Anthropology Conservation Lab (Clavir 2010; Brewer 2010; Mackie 2010), Alten recollects a possible shift in preservation thinking towards preservation in the wet state. The main considerations may have been that a fair amount of change to the materials occurred during the impregnation and drying processes and that the materials would be more useful as archaeological record in their wet state as biological specimens are stored in a natural history museum. The basic wet storage technique is thought to have been placing the artifacts in shallow trays with deionized water and biocide or alcohol and storing the trays in a cold storage environment such as a refrigerator. Not only does this preservation solution require regular maintenance, there is a major drawback to this as a long-term storage solution: the oxygen in the water will continue to degrade the basketry materials. At this point it is unclear to the authors if this was put into practice for longer than just a few years of temporary storage prior to treatment of the materials.

4. CURRENT RESEARCH

The authors examined the historic treatments of waterlogged basketry with an eye to what avenues to consider for future treatment tests. What became clear through this examination was while treatments with polyethylene glycol have become standard for basketry, determining the proper procedure and analyzing the results is challenging due to two sets of variables. The first focuses on artifact variables:

- Hardwood vs. softwood and the species of wood
- Component of tree or plant (i.e. root, inner bark, trunk, branch etc)
- Degree of deterioration, particularly whether or not the secondary cell wall is present for bonding with lower PEGs of lower molecular mass.

The second set of variables focuses on treatment design:

- Which molecular weight PEG is chosen
- Concentration of PEG
- Duration of impregnation
- Heated or unheated during impregnation
- Drying method: air drying, non-vacuum freezer drying, or freeze drying

Considering these variables the authors endeavored to find methods for determining level of deterioration of waterlogged basketry, as this variable seems key to designing successful PEG impregnation treatments. Many PEG treatments for wood rely on comparing the density of the artifact to density expected for sound wood. The assumption is that more deteriorated wood will be much less dense than sound wood because of the missing constituents. The challenge of measuring density for tiny, geometrically complex basketry fragments is compounded by the lack of appropriate comparative standards for the materials used (root, bark etc). Therefore, measuring degree of deterioration in basketry is much more difficult than measuring degree of deterioration for artifacts made of sizeable pieces of trunk wood, especially if there is a lot of material available for destructive testing, as typically afforded by timbers from shipwrecks. Visual characteristics of flexibility and hardness can provide some information. On the macro level visual and physical characteristics provide some information but can only really be valuable with personal experience comparing waterlogged basketry materials from different sites. In general root, limb, and withe materials are harder and can be more rigid than inner bark. Some of this has to do with cellular structure and some with how finely the material is split during preparation for weaving. Degraded waterlogged root can vary from hard to easily penetrated with a pin or even mushed apart between two fingers. Degraded inner bark is regularly soft, penetrable with a pin and mushed into nothing between fingers. In addition degree of deterioration can be deceptive in basketry that has woven physical forces helping to hold it together.

If there is sufficient material available to allow destructive testing, observing shrinkage and distortion with slow, controlled air-drying alone can be helpful. A well-controlled photographic set-up to allow before and after photographs on graph paper can be a useful tool in this analysis, as can measuring all dimensions possible with a precision calipers. Greater dimensional change and distortion suggests a higher level of deterioration, possibly suggesting loss of secondary cell wall for low molecular weight PEG to bond with, and may merit a PEG treatment designed to incorporate higher percentages of high molecular weight PEG.

4.1 MICROSCOPY

The next step in examination is to look at samples of the material with a microscope to begin understanding degradation on the cellular level. Transverse sections were cut from samples of fresh material as well as treated and untreated archaeological materials and examined with a Nikon Eclipse 600 polarizing light microscope and an Olympus BX-51polarizing light microscope. The transverse view was selected for examination and comparison because this view appears to show the most evidence of degradation (Florian 1990; Hoffmann and Jones 1990).

At 600x magnification degraded spruce root has some clues of level of degradation. A 2000 year old sample (fig. 9) looks similar to a fresh sample of spruce root (fig. 7) and the ~200 year old sample (fig. 8) shows some tearing of the tracheid cell walls. The variation in condition can be attributed to variations in the burial environments. Physically the cellular structure of the ~200 year old sample of spruce root is so degraded that a sample of material can be mushed apart between two fingers. The 2000-year-old spruce root sample is physically strong, maintains rigidity with pressure, and while a pin can penetrate the surface it cannot be easily pushed through the core. Neither cross section of these samples shows separation of the secondary cell way as an indicator of deterioration. This may become clearer at a higher level of magnification or with environmental scanning electron microscopy. Several samples of archaeological western red cedar inner bark were examined on the cellular level (figs. 10-12). These showed a surprising level of change in comparison to fresh western red cedar inner bark. Depending on the level of degradation the network of thin cell walls (parenchyma) and middle lamella holding the structure together was lost leaving the thick walled cells (phloem fibers) without a structure to hold them together.

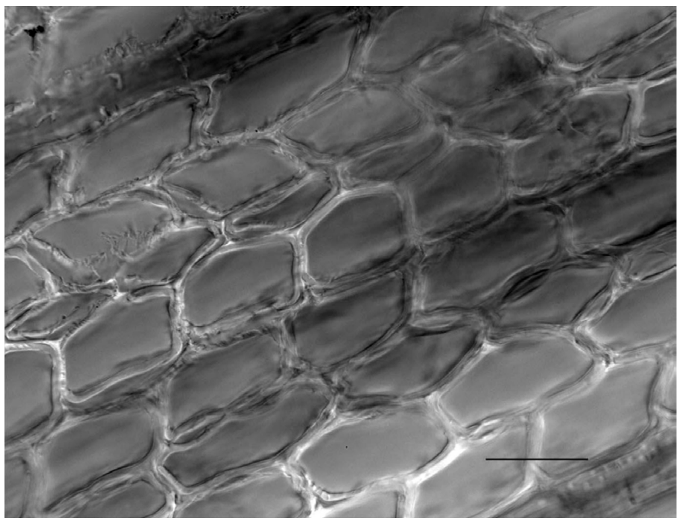

Fig. 7. Transverse section, fresh spruce root, viewed in normal illumination. Bar is 10m. (Photograph by Dana Senge)

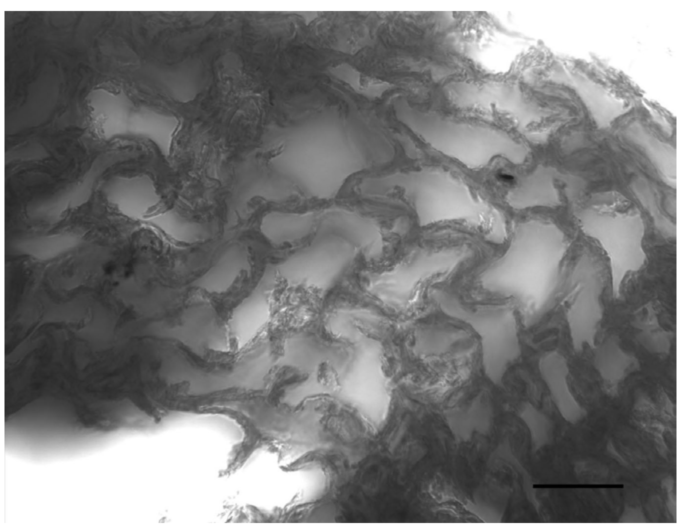

Fig. 8. Transverse section, ~200 year old archaeological spruce root from the Baranov Museum viewed in normal illumination. Bar is 10m. (Photograph by Dana Senge)

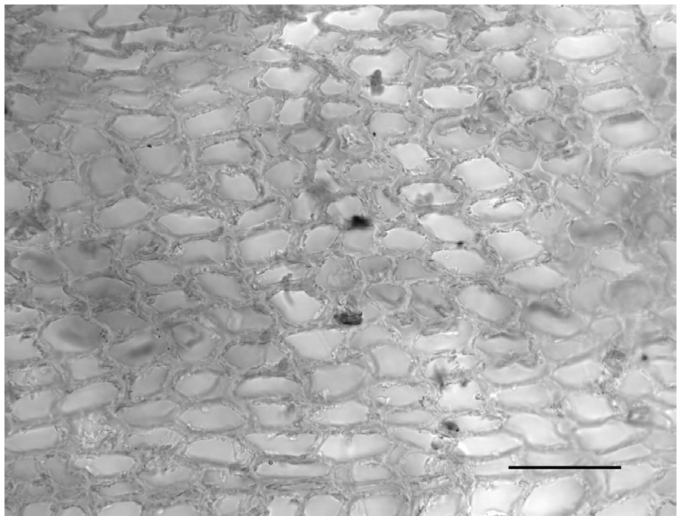

Fig. 9. Transverse section of a sample from Liyonmxetel basket, DgRm-1, 210. 2000-year-old archaeological spruce root, viewed in normal illumination. Bar is 10m. (Photograph by Dana Senge)

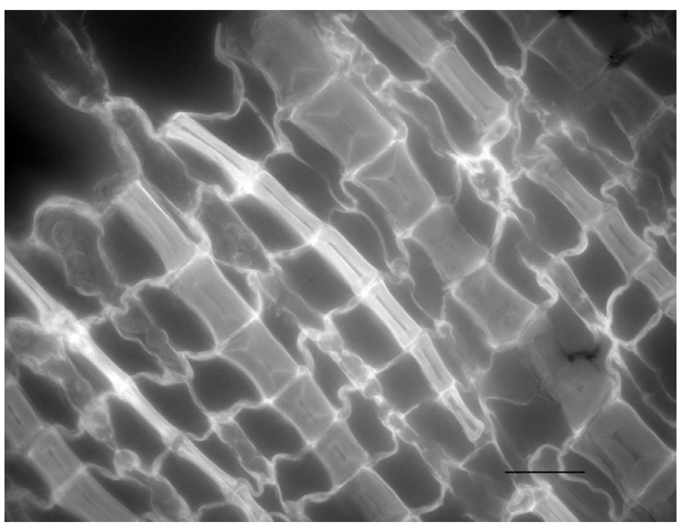

Fig. 10. Transverse section. Fresh Western Red Cedar Inner Bark viewed in UV irradiation. Bar is 10m. (Photograph by Dana Senge)

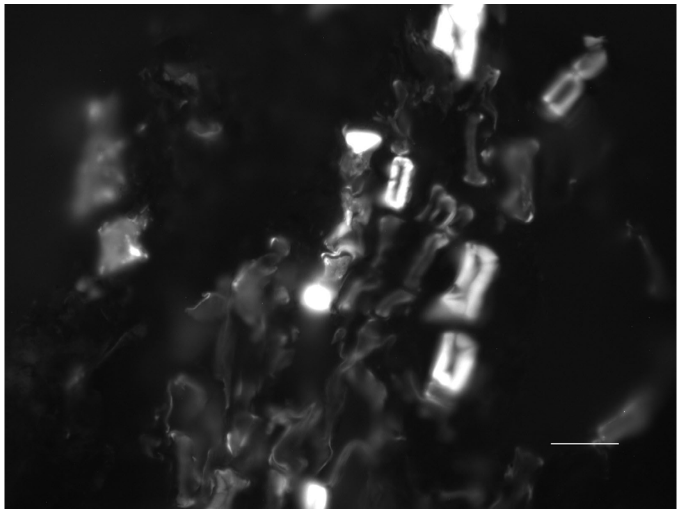

Fig. 11. Transverse section. ~700 year old archaeological cedar inner bark from Conway Basket 45SK59b-58 at the Thomas Burke Memorial Washington State Museum, viewed in UV irradiation. Bar is 10m. (Photograph by Dana Senge)

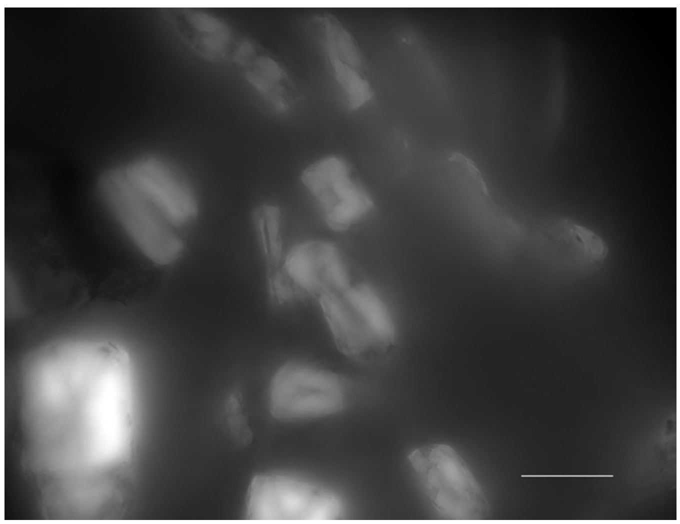

Fig. 12. Transverse section. ~500 year old archaeological cedar inner bark from Ozette Basket 45CA24B70 30-11-2 at the Makah Cultural and Research Center, viewed in UV irradiation. Bar is 10m. (Photograph by Dana Senge)

4.2 SUMMARY OF RECENT TREATMENT TESTS

While long impregnation baths with low molecular weight PEG appear to have fairly good results in reducing shrinkage and distortion there is still concern regarding long term storage of these materials with fluctuating RH and stability of materials for handling and travel. There is concern about ongoing mobility of excess liquid lower molecular weight PEG within the basketry structure.

Over the past several years Ellen Carrlee has been studying impregnation of ~4,500 year old spruce root with high molecular weight PEG and the use of heat to increase penetration. Her latest results show samples of root treated with heated 55% PEG 3350 for 3 months followed by freeze drying in a non vacuum freeze drier created a stable robust material that has withstood the fluctuations of high RH. In addition she has been testing a wide range of consolidants for friable pieces already treated with PEG and has found promising results with Butvar B98 (Carrlee and

Senge 2010).

Dana Senge has been testing low and high molecular weight PEG treatments in various concentrations and times on archaeological spruce root samples ~200 and ~2000 years old followed by slow air drying. The physical characteristics of the materials tested indicate that the most flexible samples without splits or distortion were samples treated with 4 weeks of 20% PEG 200 and 4 weeks of 40% PEG 200. Samples treated with 4 weeks of 20% PEG 400 and 4 weeks of 40% PEG 400 are more brittle, likely due to the higher molecular mass taking longer to penetrate the cellular structure of the material, therefore less impregnant is present. A longer impregnation time with PEG 400 may improve the flexibility of the material for handling. While these lower molecular weights are known to penetrate the cell wall and reduce cellular collapse, if excess is introduced to the system the molecules will remain in the lumina of the cellular structure and move around the structure with fluctuations of relative humidity, possibly leading to the weeping of PEG from the structure.

The ~2000 year old spruce root samples tested with 55% PEG 3350 for 10 weeks were rigid and snapped into two pieces when flexed, similar to the physical characteristics of historic basketry materials composed of the similar material. The ~200 year old material treated with 55% PEG 3350 was so hard after treatment it was almost brittle. The rigidity of this material may be a desirable outcome, but the level of hardness from the PEG 3500 may also be a flaw when handling the basketry (Senge 2010). The impregnations times used for these test samples may not translate to treating larger artifacts and as with all treatments using polyethylene glycol, density measurements of the bath water should be used to determine how the impregnant has moved into the structure and when treatment may be complete.

Variation in results between Carrlee's and Senge's tests can be attributed to treatment variables such as heated impregnation and drying in the freezer by Carrlee and room temperature impregnation and slow air drying by Senge as well as variables in the condition of the spruce root material. The ages of the archaeological material do not specifically indicate level of deterioration. For example: the youngest material at ~ 200 years appeared much more deteriorated that the ~2000 year old material as seen in figures 8 and 9.

4.3 FUTURE RESEARCH

This initial research into the historic treatments used on these waterlogged basketry artifacts has only scratched the surface of information these materials may hold. Further understanding of the individual burial environments and age may help predict level of degradation without specialized instrumentation. Burial environment is a major influence on condition of artifacts and thus the appropriate treatment design. Throughout the research summarizing past treatments of basketry materials the artifacts were examined independently of burial environment information. This is partially due to burial information being inconsistent. One article or note may list the pH of the burial environment and the next may only describe the soil in terms such as "sandy" or "clayey". Understanding soil chemistry and collaborating with a plant pathologist or deterioration biologist is needed to fully round out this body of work and understand burial degradation observed in the materials.

Use of microscopy to create a reference set of images may be the key to identifying their level degradation. Presence or absence of secondary cell wall seems to be crucial for the application of the proper molecular mass of PEG, but its observation is exceedingly difficult for conservators who are familiar with general polarized light microscopy but do not have specialized plant anatomy training. Most of the major reference articles and texts describing deterioration of cellular structures involve the expertise of wood anatomists with considerable specialized training and experience. Perhaps collaboration with these professionals and refining the understanding of the structures with supplementary environmental scanning electron microscope images could create a reference set of cedar and spruce images that may help interpret what is seen through more accessible polarized light microscopy.

This study focuses on some of the major materials used in basketry in the region: western red cedar inner bark and spruce root. However, other materials were used such as tule reed, cherry bark, and sweet grass. The treatments used on these materials and their results should be examined as well.

Future research into treatment solutions may include examining treatment methods using PEG 2000. Initial testing with higher molecular mass PEG in spruce root is promising. Perhaps PEG 2000 may afford the advantages of the large molecule without excessive hardness.

This examination into treatments has shown that some success is found with a two stage consolidative approach. Perhaps it is time to consider the treatment of waterlogged basketry as impregnation with a low molecular weight PEG followed by consolidation with Butvar 98 or Ethulose.

Another treatment option that may be important to examine the impregnation of the materials with alkoxysilanes or silicone oil. This treatment technique has been considered controversial for many years but it is important to understand the advantages and disadvantages of the technique as more people turn to it for the conservation of waterlogged materials. There is only one attempt to treat waterlogged basketry using silicone oil known to the authors. Unfortunately the basketry material didn’t survive the treatment process and could not be be assessed by the authors. While the poor results of this treatment may have been operator error, it underscores a major challenge of working with this method: when it works well it works beautifully, when it doesn’t work well it can be disastrous. Is this an acceptable risk? The other treatment methods used for basketry may not be perfect, but the treatments can be adjusted, even partially reversed and re-done if mistakes are made in the treatment process.

While the silicone treatment process may be successful for wood, root and limb based materials it may not be appropriate for degraded inner bark. As described in an earlier section, archaeological inner bark samples viewed by the authors has very little structure left, leaving very little to for the silicone oil to bond to and support in the treatment. Current understanding of the silicone oil treatment process is that the consolidant bonds covalently to the interior surfaces of the lumina and enters much of it enters the middle lamella. Very little of this remains with the archaeological inner bark, additional research should be performed in understand the deterioration of the inner bark and how silicone oil would enter and support this system.

There is a great deal of science behind the decisions and treatments of waterlogged basketry, however the actual treatment of the materials is still an art for each method selected, and published results on the archaeological material are sparse.

5. SUMMARY

The authors learned a great deal about the tremendous amount of research performed by others in the field of conservation of waterlogged basketry materials. The past preservation treatment techniques for waterlogged basketry have been effective in preserving these materials for later generations. However, many of these artifacts are difficult to handle, study, and exhibit due to issues of stability or excessive conservation materials present.

The conservation of waterlogged basketry materials is still a complex challenge and conservators in several labs in the Northwest are considering new variations of treatment solutions in order to improve overall physical characteristics of the treated artifacts. Refining the palette of treatment is ongoing through continuing research with low molecular weight PEG and more in depth research with high molecular weight PEG.

While the more recent treatments of longer impregnation times with PEG 400 and PEG 3350 have made some major strides towards basketry materials that appear stable and can be gently handled a deeper understanding of level of deterioration and desired outcome is required to refine these techniques. Fairly degraded material appears to require additional consolidation when impregnated with a low molecular weight. The recent test of PEG 3350 on spruce root should be expanded to a wider range of levels of degradation to understand where this tool is most useful.

The structure of the archaeological western red cedar observed in figures 11 and 12 may indicate that the basic strategy of using an impregnate to bulk up cell walls and possibly fill the lumina isn't truly effective with this material. No doubt the polyethylene glycol is aiding in preservation, possibly as a waxy consolidant holding the phloem fibers in the recognizable shape of inner bark than actually contributing the cellular structure that truly no longer exists.

Many important archaeological sites along the Northwest coast are wet. In an ideal world, excavation of these sites would be well planned with ample resources for treatment. The reality often involves remote sites done on a salvage basis with little funding. The methods to analyze and treat basketry from these sites needs to be accessible to conservators and archaeologists working without the benefit of wood anatomy specialists and scanning electron microscopy, and even to collaborating with archaeologists who may need to treat this material remotely under the guidance of a conservator.

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NOTES

1. Plymul adhesive is a polyvinyl acetate emulsion produced by Reichold Chemical in the 1960s.

2. Firewater and Houston #3 are referenced in the treatment information described in Nordquist 1976 and Bernick 1991. To date, the authors have been unsuccessful in finding product information associated with these brand names.

3. Qwu? Gwes is the name given to the Squaxin Island tribal heritage wet site at Mud Bay in the south Puget Sound area of Washington State. This name, given by the Squaxin Tribe holds the meaning 'coming together, sharing' (Croes et al. 2005).

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