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Candied Cedar Bark: The Treatment of Waterlogged Western Red Cedar Bark Using Sucrose

Abstract

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Western red cedar bark has been used for centuries by the First Nations peoples of the Northwest Coast; however the objects made from this material rarely survive in archaeological sites except for those objects found in waterlogged conditions. The survival of these materials is dependent upon their conservation treatment following excavation. Traditionally waterlogged archaeological cedar bark has been treated with polyethylene glycol 400 (PEG 400), but this treatment has received mixed reviews and does not always produce a predictable result. Sucrose was used successfully as an impregnant for waterlogged wood for many years, but so far it has not been used on bark. The purpose of this investigation was to determine whether waterlogged western red cedar bark can be successfully treated using sucrose. This research employed modern waterlogged samples of western red cedar bark prepared at the Canadian Conservation Institute (CCI), which had been soaking in water for fourteen years. Some of this sample material had been further degraded to mimic the deterioration present in archaeological waterlogged cedar bark. A third set of samples came from a supply of archaeological waterlogged western red cedar bark recovered from the Lachane site in the harbour at Prince Rupert, British Columbia. The samples were cut to a uniform size and each was soaked in solutions of increasing concentration of sucrose to a maximum concentration of 70% w/v sugar in water. Soaking times varied from two to six months. The samples were air dried, the most common method of drying associated with sucrose impregnation. A group of control samples that remained untreated was air dried at the same time as the treated samples. A second set of control samples was treated with PEG 400 as this is the standard method used to treat waterlogged cedar bark at CCI. To determine the degree of penetration of the sucrose, the samples were examined using scanning electron microscopy. The effectiveness of the treatment was also assessed as regards the dimensional stability of the samples, final appearance, and handling properties. The sucrose treated samples demonstrated good dimensional stability, although they were not flexible, they were not brittle, which is encouraging. The samples treated with sucrose did darken significantly following treatment, however, which may be a deterrent from using this method.

Introduction

The Northwest Pacific Coast of Canada is home to a great many First Nations cultures and communities. Although there are many differences culturally, one of the great commonalities between all of these groups has been their reliance on the western red cedar tree, *thuja placita,* for the construction of a huge variety of cultural materials. In archaeological conditions, organic materials, such as those produced from the western red cedar tree, rarely survive to the present day, except in the case of waterlogged and frozen sites. Considering that approximately 90% of the cultural materials produced by these groups were made of organic materials, it is an important discovery when such waterlogged sites are uncovered (Macdonald, 3, 1977). The bark was woven to create mats, baskets, and clothing. Due to their rarity in the archaeological assemblage every effort should be made to ensure the survival of objects made of this material for future study.

There have been a great many studies conducted and articles written about the preservation and consolidation of waterlogged archaeological materials made from wood; however, there has been very little investigation into the consolidation and preservation of waterlogged bark of any kind. The most commonly used materials for the consolidation of wood today are Polyethylene Glycol (PEG) and sucrose. There has been one study for the treatment of cedar bark using PEG, and its conclusions will be discussed below (Grant, Young, and Bilz, 1996 and 1998). To date sucrose has not been tested on bark.

Bark

Bark provides the waterproofing and protection layers for trees. It is made up of several layers. The inner bark is made up of phloem and the inner phloem, and the outer bark is a layer of cork cells that are no longer living. The inner bark, more specifically the inner phloem, is what is used for basketry weaving (figure 1).

Figure 1. A section of cedar bark freshly peeled from the tree. The inner bark (inner phloem) the whiter layer shown here, is what is used for weaving.

There are three major types of cells in the inner phloem of cedar bark, the fibre cells, the parenchyma cells and the sieve cells. The cells of the inner phloem are layered in sheets. There are rows of parenchyma cells, described by Mary Lou Florian as being "delicate," that were used for storing food. Layered next to the parenchyma cells were the sieve cells that were very porous and used for transporting food in the phloem (Florian, 14, 1977). There is another layer of fibre cells that are very thin and long, with very small inner lumen, making them very strong. This layering of cell types allowed the cedar bark to be easily pulled into strips, which was one of the characteristics that it made it ideal for use in basketry.

The cellular structure (particularly the small inner lumen) makes penetration by water and impregnants for the consolidation of objects made from cedar bark extremely slow. In any piece of wood the penetration proceeds most quickly in a longitudinal direction, as the water, or impregnant, can travel along the same pathways that were designed to carry water and food. In cedar bark, these cells are very small. The bark, especially when prepared for weaving, is a very long and thin piece of material with the cell alignment following the length of the strip. Water can only penetrate easily along the cross-sectional plane and this plane has the smallest surface area. Water, or an impregnant, might be able to penetrate into the tangential plane if the bark is very deteriorated or if breaks have opened up the cell walls. Generally the movement of any material through the cellular structure of cedar bark is very slow. There are also a number of extractives in the bark that act as natural waterproofing and water repelling agents, such as suberin, that are present in large quantities in the bark. These substances also act to slow the movement of water and impregnants within the bark (Fraser and Swan, 1978). In heavily

deteriorated barks, it is unknown how much of these materials remain, or how much of an effect they will have upon the impregnation process. All of this adds up to a material that is difficult to treat by impregnation. Bark is a material that will require a much longer length of time and a very small molecular weight material in order to impregnate fully.

Reasons for Impregnation

When cedar bark is preserved in a waterlogged archaeological site, it may take many forms. The most common use for cedar bark was basketry. When recovered from waterlogged sites, basketry is often fragmentary, and in a heavily degraded condition. Especially when fragmentary, there is nothing really holding the basketry elements together. If these fragments are allowed to air dry without any impregnation, they can distort, warp, shrink, and become very brittle. Impregnation can improve the state of the fragments to ensure their survival for future study. By impregnating and strengthening the cells of the bark, one can minimize any shrinkage or distortion of the fragments. Impregnants containing materials with a low molecular weight will help to keep the cell walls from shrinking by bonding to the materials in the cell walls and adding strength so that the cell walls will not collapse. In heavily degraded cells, where the cells walls have very little cellulose left, impregnants with a larger molecular weight can fill the lumens of the cells to keep the cell walls from collapsing. Impregnants help to maintain the original appearance of the basketry as much as possible.

Polyethylene Glycol

Polyethylene glycol (PEG) has been used as a bulking material and impregnant for wood since the early 1970's. The method has been thoroughly researched and used in the field of waterlogged wood conservation. A study conducted at the Canadian Conservation Institute, by Tara Grant, Greg Young, and Malcolm Bilz in 1996 and 1998, tested different weights and concentrations of PEG to determine which provided the best results for cedar bark. They used new samples of cedar bark and a standard sample size. In the end they concluded that the best results were obtained using PEG 200, at a minimum concentration of 20% v/v in water, for more than four months. They did note that the results were still not optimum as the cedar bark required a very long time to impregnate fully and did not always absorb the PEG (Bilz, Grant and Young, 1996 and 1998). In discussions with Tara Grant, it has been further discovered that

the response of collections managers and curators was not always favourable to the treatment discussed in her research. In general the fragments were found to be too brittle, had a poor colour, and were generally dry looking. There is also the question of the volatility of PEG 200. Tara Grant has been involved in the pursuit of better solutions for the treatment of basketry with PEG. In her own treatments she has turned to using PEG 400, at a 20% v/v in water concentration.

Once an object has been impregnated with PEG, it is extremely difficult for an adhesive to stick to the waxy surface of the object. This is especially problematic with fragmentary cedar bark because it does not allow for the consolidation of the fragments. Fragments may be held together only by the alignment of the cedar bark strands. The cellular structure of cedar bark also lends itself to shedding. PEG treated cedar bark is especially prone to shedding. Being able to use an adhesive on the fragments would help to reduce this problem.

Sucrose

Sucrose was first suggested as an impregnant for waterlogged wood by James Parrent in an article published for *Studies in Conservation* in 1985. Subsequently there were many other studies undertaken, particularly in Europe. Most of the studies were conducted or managed by Per Hoffman, who in the 1990's thoroughly researched and championed the use of sucrose as an impregnant for waterlogged wood, (Hoffman, 1990, 1993, 1996, 1996). Sucrose was sought as an alternative to treatment with PEG for large waterlogged wooden artifacts such as ships, which were extremely difficult and costly to impregnate with PEG, a process that would take a number of years. The other advantage of using sucrose as an impregnant over PEG was that the treated objects could be safely air dried. The lower molecular weights of PEG generally require vacuum freeze drying in order to dry properly. The results of the various studies were generally good. Sucrose was found to have a good level of penetration and an acceptable level of Anti-Shrink Efficiency (ASE) which meant that it prevented warping and shrinkage of the wood upon drying (Hoffman, 1990).

The sucrose treatment was also determined to be much cheaper and faster than PEG impregnation. There were, however, problems with using sucrose that were outlined by Hoffman in his report of 1996, "Sucrose for Waterlogged Wood – Not So Simple at All." In this

report Hoffman outlined the various drawbacks to using sucrose. The first was that the solutions were prone to developing microbial growth, as sugar is essentially food for a great many different types of bacteria and moulds. Hoffman noted that these growths changed the sugar molecules, prevented impregnation, and sometimes left the wood sticky after treatment. A second problem with sucrose was that it prevented the objects after treatment from being kept in an environment with a relative humidity (RH) above 70%. At this RH the sucrose would become tacky and the surface of the object would become sticky. The third major complaint against sucrose was that it would attract insect activity. There was one study conducted to test the attractiveness of sugar treated wood to termites, but the study largely showed that this was not a real concern (Noldt, 1993).

There are two other potential issues with the characteristics of sucrose and its appropriateness as an impregnant. The first is that it is in crystal form at room temperature. This structure works well for wood, but it is unknown how it will react with bark. The molecular size of sucrose is also larger than that of the lower molecular weight PEGs. This may cause difficulties with impregnation.

Research Experiment

The experiment was conducted in an attempt to determine whether or not sucrose could act as a suitable alternative to treating waterlogged cedar bark basketry with PEG. There were several variables tested. The sample materials came in three different grades: almost new, artificially degraded, and archaeological. Length of time in solution varied from two, three, four and six months. The temperature of the solution varied between room temperature and an elevated temperature. The rate of increasing the concentration of sucrose in the solutions was varied with some of the solutions increased concentration at a very gradual rate, and others at a more accelerated rate. There were also several controls, samples that remained untreated, but were dried at the same time, as well as samples that were treated with PEG 400. All of the samples were examined for dimensional stability, colour, handling properties, and sucrose intake. All samples were examined under Scanning Electron Microscopy in order to determine what was happening at a cellular level.

Experimental

The first stage of the experiment was to determine the best means of artificially degrading the sample material in conditions that would mimic those found in archaeological basketry. Then the samples were impregnated with sucrose followed by air drying. The samples were examined by stereo microscopy, scanning electron microscopy, and photography.

Samples and Their Preparation

Some samples were archaeological and the rest were samples that had not been used for basketry. This second group had been kept waterlogged for fourteen years (since March 19, 1997) at the Canadian Conservation Institute. Some samples were used in this condition as some degradation had taken place. Other samples were degraded further to resemble more closely the condition of heavily degraded basketry in archaeological sites. All samples were waterlogged and were cut to a standard size. Each sample measured 4.5cm x 0.5cm x 0.2cm. This size was chosen as it is very similar to the size of strips often used for basketry. The length was determined by the amount of sample material available and also the fragmentary nature of most archaeological basketry.

The artificially degraded samples were prepared by soaking in a 1% concentration solution of sodium hydroxide for one week in order to degrade the cellular structure of the cedar bark. The samples were then rinsed until the water returned to a neutral pH, they were then ready for impregnation with sucrose.

A collection of archaeological samples was donated by the Canadian Museum of Civilization. This collection of cedar bark cordage was most likely recovered from the Lachane wet-site in Prince Rupert harbour. These samples are very important to the current research as they are archaeological and so represent the same level of deterioration in other basketry samples that may be subject to this treatment.

A collection of control samples remained untreated and waterlogged and another collection of control samples were treated with PEG 400 and then freeze dried. These samples were controls for physical comparison of dimensional change and handling properties,

specifically texture, colour and flexibility. There were control samples for each grade of sample material, normal (new), degraded and archaeological. Some of the untreated controls were kept in the oven to determine if the heat was causing any damage to the bark.

Sample Material	Source/preparation
N: Normal (new)	Waterlogged at CCI for 14 years
D: Degraded	Waterlogged at CCI for 14 years and then further degraded in a 1% solution of NaOH for 1 week
A: Archaeological	Archaeological cedar bark from the *Lachane* site in Prince Rupert Harbour, donated by the Canadian Museum of Civilizations with help from CCI.
C: Control	Samples of each type of material (illustrated above) left untreated

Table 1. Summary of Sample Materials

Impregnation

After the samples were cut to a standard size, they were carefully photographed on a millimetre grid, measured, and weighed on an analytical balance before the samples were put into their respective sucrose solutions. The solutions were kept in Bernardin Jam Jars as they are self-sealing, help to prevent evaporation and can also withstand higher temperatures. The solutions were changed once a week to prevent microbial growth and avoid the need for an anti-microbial agent in the solutions. For each set of sample materials there was a group impregnated at room temperature (23°C) and another group kept at elevated temperature (50°C). There was also a group impregnated with sugar at a gradually increasing concentration and another group at a more accelerated rate. The rate of increase in the sugar concentration within the solutions is summarized below in table 2. The archaeological material had to have a different gradual rate from the other sample materials as it only had a total of three months to soak in solution due to time constraints. For each of these methods of impregnation, including the control materials, some samples were removed after two months, three months, four months, and six months.

Speed of Impregnation	2 weeks	2 weeks	2 weeks	2 weeks	2 weeks	2 weeks
A: Accelerated	30%	50%	70%			
G1: Gradual	10%	20%	40%	50%	60%	70%
G2: Gradual	20%	35%	50%	60%	70%	

Table 2. Rates of Impregnation

Drying

Once the impregnation process was completed, the samples were air dried in a controlled manner. The samples were removed from solution; the excess sucrose gently rinsed from the surface using tap water, and then carefully weighed on an analytical balance. The samples were then placed on a screen of nylon net on a raised rack to allow airflow. A second layer of nylon net was placed on top of the samples. This allowed for a small amount of restraint on the samples, but not enough to prevent them from warping. By not restraining the samples, one was able to see if there were any differences in the way the untreated samples behaved compared to the treated ones.

Examination

Following the drying process, the samples were measured to determine if any shrinkage or distortion had taken place. The percent shrinkage was calculated, followed by the Anti-Shrink Efficiency (ASE). The ASE is the standard measurement used to establish the success of an impregnation treatment for waterlogged materials. Any percentage above 75% is deemed to be successful. An ASE of 100% indicates that the sample has retained its waterlogged thickness. To calculate an ASE the equation is: $\frac{shrinkaage\ of\ control - shrinkage\ of\ sample}{shrinkage\ of\ control} \times 100 = ASE.$

The samples were then compared as to their physical properties, appearance, flexibility, and overall handling properties. The physical qualities were also compared with the control samples that had been treated with PEG 400 and freeze dried. Comparative photographs were taken and the general handling and flexibility was determined by feel. Although these empirical observations were not scientific they were an important factor in the success of the treatment. The samples were then sectioned using a sharp razor blade and photographed using Scanning Electron Microscopy (SEM) to determine if there was sugar present in the cells of the cedar bark, either in the form of crystals or as a layer covering the cell walls. The cedar bark samples were compared to new cedar bark, and the control samples in order to determine the difference in cellular structure, whether any shrinkage or distortion had taken place, as well as the presence or absence of sucrose.

Problems Encountered

Even with changing the solutions once a week, there was still fungal growth present in the solutions kept at room temperature. The accelerated temperature eliminated any mould concerns for those samples. The mould was present both on the sample material and as a cloud in the solution. By changing the solutions once a week, the mould did not become a large problem, as very little mould was ever permitted to grow either on the object or in solution. The mould reappeared each week until the solutions reached 70% sucrose w/v in water. After this concentration was reached, the issues disappeared for the most part. Regardless, there was no difference in the end between samples which had mould problems and those that did not. The presence of mould in the solutions did not affect the handling properties of the samples, or the amount of sucrose absorbed into the cells. There were no differences in those samples that had mould issues and those that did not on either the microscopic or macroscopic level. The key point here is that as long as the mould levels are controlled, and kept to a minimum, it will have minimal effect on the final product following treatment. If the mould is allowed to grow unchecked, the treatment may be unsuccessful as the materials may become darkened and sticky.

The second problem encountered was the extraction of water soluble materials from the cedar bark kept at elevated temperatures. The solutions changed colour in all of the solutions kept at elevated temperature. This occurred in both the control solutions (only water) and the sucrose solutions. It should also be noted that the archaeological sample solutions did not darken as much as the solutions that contained the normal and artificially degraded samples. This could be due to the fact that there were fewer extractives remaining to be drawn out of the archaeological samples.

Results and Discussion

Dimensional Change

In general, the results of the experiment were very encouraging. After only two months in solution, the samples demonstrated the least dimensional stability; four months in solution was much more encouraging with more samples exhibiting lower percent shrinkage, and a better ASE

result. Six months in solution demonstrated the best results, with many samples showing 0% shrinkage and 100% ASE. It must be noted though that even when the samples appeared to have undergone a significant amount of shrinkage, the numerical values are very small, maybe a millimeter. The samples treated with PEG 400 demonstrated excellent dimensional stability with no shrinkage and 100% ASE for both the four and six-month results. The archaeological material was much more difficult to measure as the cordage had such a different structure from the other sample materials. When impregnated with either sucrose, or PEG, the material was able to maintain its shape, and twisted structure, but when left untreated the materials completely delaminated, making measuring for ASE values and percent shrinkage values impossible. One can see the results below in figure 2. Even the one treated sample that delaminated slightly is much more stable than the untreated controls. All of the results for the dimensional change of the samples are summarized below in table 3.

Figure 2. The top row of archaeological samples have been treated with sucrose. The bottom row were the untreated controls. One can see the difference in delamination and stability.

Speed of Impregnation	Temperature of Impregnation	Sample	% shrinkage width at base	Anti – Shrink Efficiency (ASE)	Warped?
Accelerated Impregnation (30%, 50%, 70%)	Elevated Temperature 50°C	AET-A2	25%		Same shape
		AET-A3	20%		same shape
		AET-D2	6%	33%	Warping across width and length
		AET-D4	7.69%	75%	Natural bend and warping along width
		AET-D6	0%	100%	no warping
		AET-N2	14%	-100%	Natural bend in sample, slight warping across width, not as curved as BT
		AET-N4	7.14%	50%	natural bend along length
		AET-N6	8.3%	50%	no warping
	Room Temperature 23 °C	ART-A2	0%		Same shape, some minor delamination
		ART-A3	25%		slightly delaminated: same shape
		ART-D2	0%	100%	Split in bark, some warping across width
		ART-D4	7.69%	75%	natural bend and minimal warping along width
		ART-D6	0%	100%	warping across width
		ART-N2	9%	-300%	Not as bent as before treatment, no warping across width
		ART-N4	15.38%	33%	warping along length and width
		ART-N6	0%	100%	no warping
Untreated	Elevated Temperature 50°C	CET-A3			completely delaminated and shedding
		CET-D4	33.33%		warping along length and width
		CET-N4	8.33%		natural bend along length warping along width
PEG 400 Treated	Room Temperature 23 °C	CPEG-A3			Same shape
		CPEG-D4	0%		natural bend at tip
		CPEG-D6	0%		no warping
		CPEG-N4	0%		no warping
		CPEG-N6	0%		no warping
Untreated	Room Temperature 23 °C	CRT-A2			Completely delaminated
		CRT-A3			completely delaminated and shedding
		CRT-D2	23%		Natural bend in sample, warping across width
		CRT-D4	42.86%		natural bends and warping along length and width
		CRT-D6	50%		huge warping
		CRT-N2	9%		Natural bend in sample, slight warping across width
		CRT-N4	23.08%		natural bends and warping along width
		CRT-N6	17%		slight warping
Gradual Impregnation (10%, 20%, 40%, 50%, 60%, 70%)	Elevated Temperature 50°C	G1ET-D4	20%	75%	warping along length and width
		G1ET-D6	8.3%	75%	no warping
		G1ET-N4	25%	50%	no warping
		G1ET-N6	0%	100%	no warping
	Room Temperature 23 °C	G1RT-D4	18.75%	25%	warping along length and width
		G1RT-D6	7.6%	75%	no warping
		G1RT-N4	7.69%	66%	no warping
		G1RT-N6	0%	100%	no warping
Gradual Impregnation (20%, 35%, 50%, 60%, 70%	Elevated Temperature 50°C	G2ET-A3	0%		delaminated but shame shape and stable
	Room Temperature 23 °C	G2RT-A3	15%		same shape

Table 3. Dimensional Change.

Colour

The differences in colour produced by the various treatments were quite stark. Colour is very important for the success of a treatment. The untreated samples were quite dark and had a dullish appearance, almost a grey tinge. This was present in all sample types. The PEG treated samples were very close in appearance to new cedar bark that had never been waterlogged, which is really positive. In past PEG treatments (using different molecular weights) one of the complaints was a dark colour, so finding a better colour result with PEG 400 was very encouraging. The sucrose treated samples were very dark. This was especially true of the archaeological material (figure 3). With the newer material, there was a difference in colour after four months and six months, and on the recto or verso, but the samples were still much darker than the PEG treated materials and even the untreated controls (figures 4 and 5).

Figure 3: Colour difference between the PEG-treated, untreated and sucrose-treated archaeological samples after three months

Figure 4. The colour change between the sample materials on the recto. From left to right, New cedar bark (never waterlogged), PEG-D4, ART-D2, ART-D4, ART-D6, CET-D4.

Figure 5. The colour change between all the samples on the verso. From left to right, New cedar bark (never waterlogged), PEG-D4, ART-D2, ART-D4, ART-D6, CET-D4.

Handling Properties

The untreated samples were very rigid and extremely brittle. They were prone to shedding and delamination, and in general were highly unstable. The PEG treated samples were more flexible than the other samples. The surface of the bark was waxy, and most samples were cool to the touch, indicating that some PEG remained on the surface or was being leached out. The PEG samples were also very prone to shedding (figure 6), especially the archaeological materials. The sucrose treated samples of all types displayed the same handling properties, although to different degrees. They were rigid, but not brittle, and could be safely handled. The surface texture of the bark felt the same as new, never waterlogged bark. The surface was not cool or sticky. There also seemed to be some internal adhesion provided by the sucrose. This was especially evident in the archaeological cordage, as the strands did not delaminate as they did in the untreated controls (figure 2).

Figure 6. Illustrating the shedding common on the PEG controls

Scanning Electron Microscopy

The scanning electron microscopic images of all the samples clearly show what was happening inside the samples. In general the untreated samples had a great deal of deformation of the cells upon drying; the degraded samples deformed more than the normal samples (figures 7 and 8). In the room temperature and the elevated temperature controls, the elevated temperature degraded samples deformed the most as there was complete cellular collapse (figure 7). This indicates that the elevated temperature was causing further deterioration of the cedar bark to occur. New cedar bark that had never been waterlogged was also imaged (figure 9); the cells deformed only slightly when they were dried naturally, one can also see other materials between the cells, possibly the natural extractives present in the cedar bark (figure 9). The PEG controls behaved most like the new cedar bark. The PEG penetrated only into the cell wall; it did not fill the lumen (figure 10).

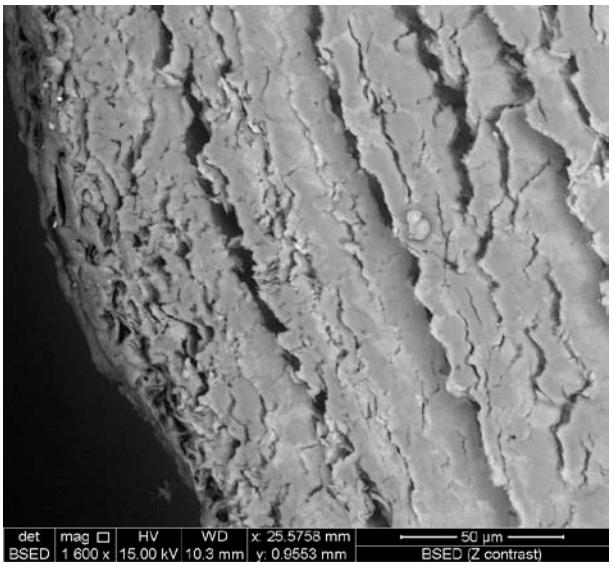

Figure 7. CET-D4, showing complete cellular collapse

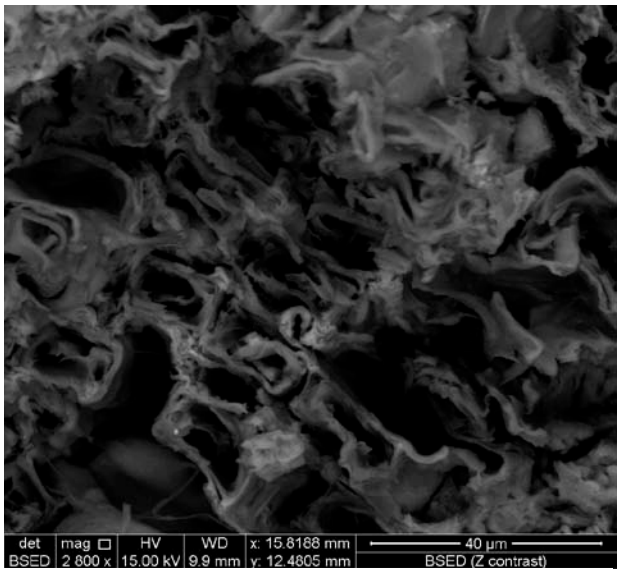

Figure 8. CRT-D4, showing distortion of the cells

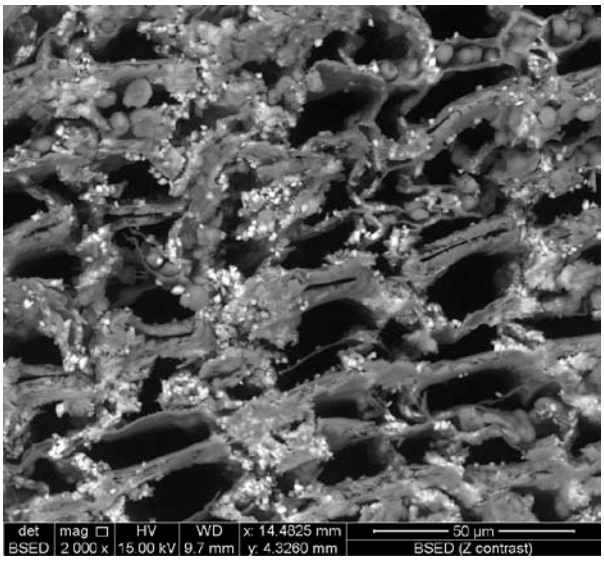

Figure 9. CNEW, new cedar bark that has never been waterlogged.

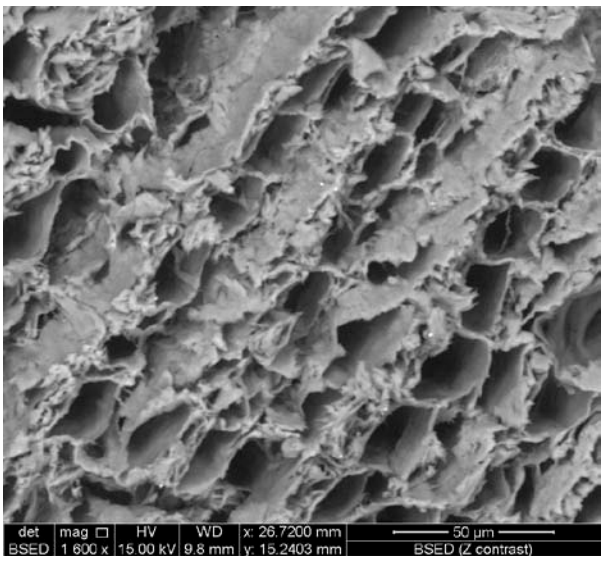

Figure 10. CPEG-D4, illustrating the location of the PEG in the cell walls and not in the lumen

The PEG treated samples retained the shape of the cells the best of all the samples. The thickness of the PEG treated samples on a macro level most closely resembled the thickness of the samples when they were still waterlogged (ASE 100%) (figure 11). This is a very good illustration of how effective PEG can be.

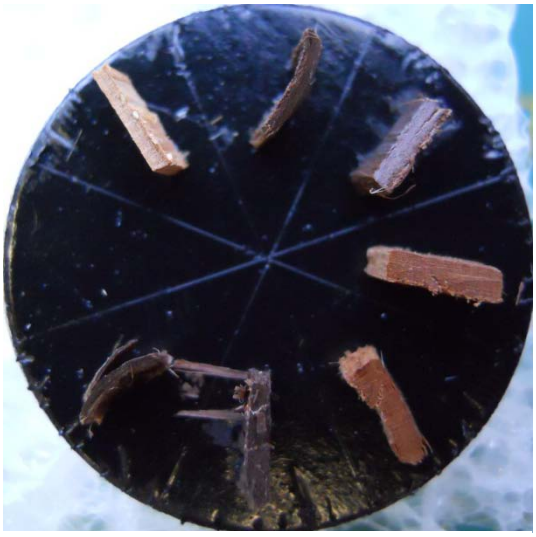

Figure 11. Illustrating the swollen nature of the PEG samples compared to the other controls. Clockwise from top: CRT-D4, CRT-N4, CPEG-D4, CPEG-N4, CET-N4, CET-D4, SPACE, CNEW.

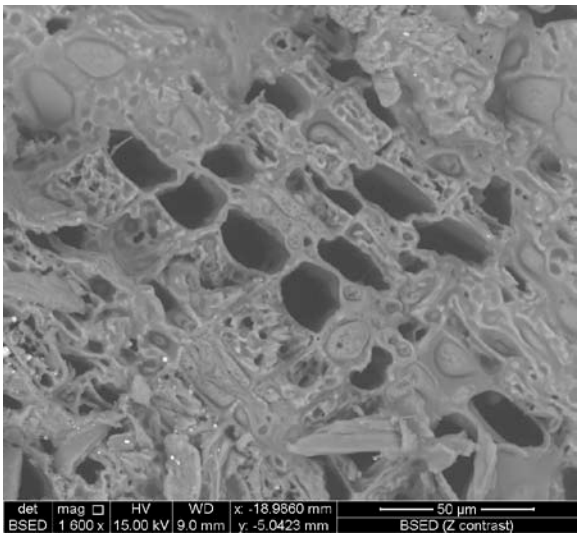

Figure 12. Illustrating how the sucrose was depositing in the cells, only in the lumen, as an amorphous material, and some cells remained unfilled.

The sample materials treated with sucrose displayed many qualities that were expected by the author. The sucrose was filling the lumens of the cells, and not penetrating into the cell walls. The sucrose was present in the cell's lumen as an amorphous material rather than crystals (figure 12). This could be due to the sample not being completely dried all the way through upon sectioning, or possibly due to the sucrose combining with some of the extractives in the bark to produce a mixed substance. The sucrose did not fill all of the cells in any of the samples; there were empty cells present in all sample materials. One can also see, under low magnification, the great difference between the untreated samples and the sucrose treated samples. The untreated samples are entirely distorted shrunken and warped, but the treated samples retain their shape (figures 13 and 14).

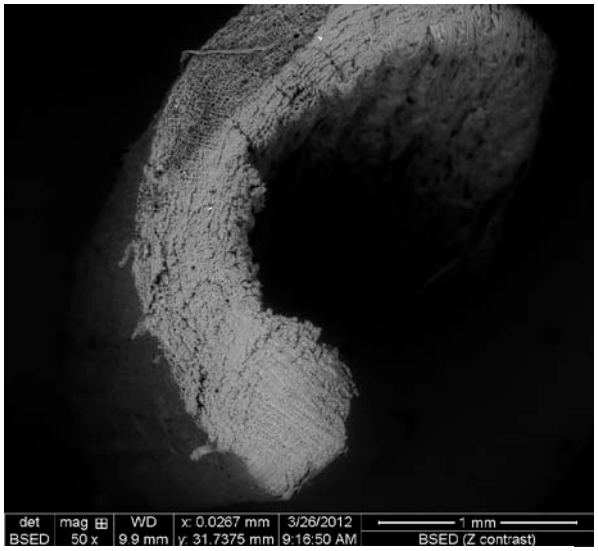

Figure 13. CRT-D6. An untreated control sample after drying.

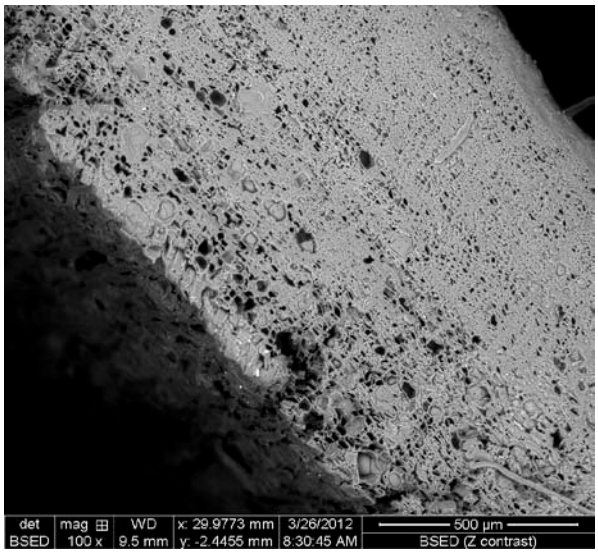

Figure 14. G1ET-N6. A sucrose treated sample. One can see the difference that the sucrose makes on a cellular and a macro level.

The scanning electron microscopic images were taken only of the newer samples materials, and the artificially degraded sample materials. The archaeological material was too fragile for testing. The cordage crumbled when sectioning was attempted. The results discussed here are only of the samples treated for four and six months.

Of the samples treated with sucrose the degraded samples appeared to absorb more sucrose than the normal samples. This outcome is logical as there would be more pathways through which the sucrose could travel and penetrate into the degraded cedar bark. There was some distortion of the cellular structure in all the sample materials; this was expected due to the slight dimensional change present on the macro level. The degraded samples appeared to have more cellular distortion than the normal samples (figures 15 and 16). This result is also expected as the degraded cells have less inherent strength. Even though the degraded samples had more sucrose in their cells, they still had a greater level of cellular distortion.

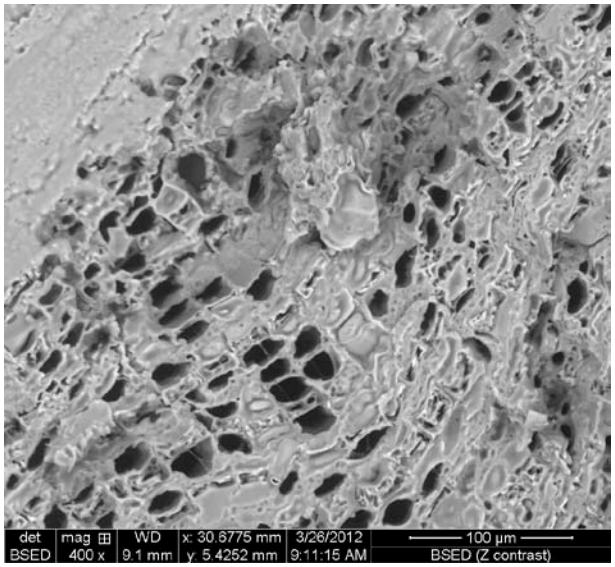

Figure 15. ART-D6. More cells contain sucrose in this degraded sample than in the normal sample given the same method of treatment pictured at right there was more cellular distortion as well.

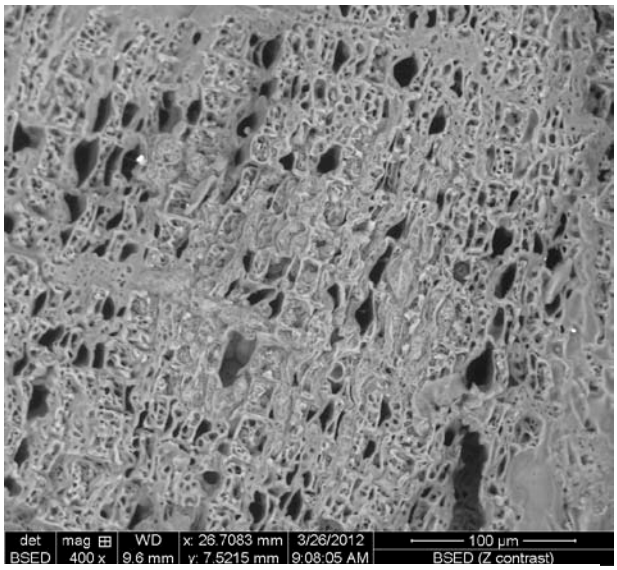

Figure 16. ART-N6. Sucrose distribution, the cells retained their shape much more than in the degraded sample at left.

One could also see the difference between the sample materials treated at room temperature and those treated at an elevated temperature. At room temperature the sample impregnated at a gradual rate of increasing concentration had sucrose deposited more evenly throughout the cell structure. The newer material had much fewer filled cells (figures 17 and 18). At an elevated temperature, the difference was more difficult to observe. The increased temperature increased the rate of diffusion, and so the differences between gradual and accelerated impregnation were nullified (figures 19 and 20).

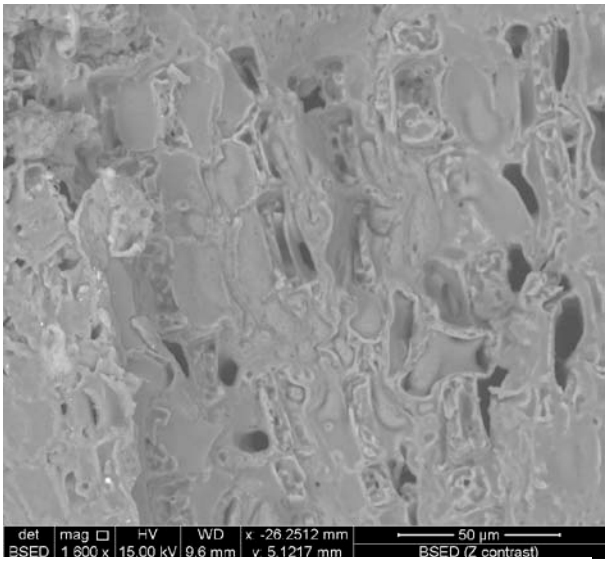

Figure 17. G1RT-D4. An artificially degraded sample treated at room temperature. Showing even distribution of the sucrose.

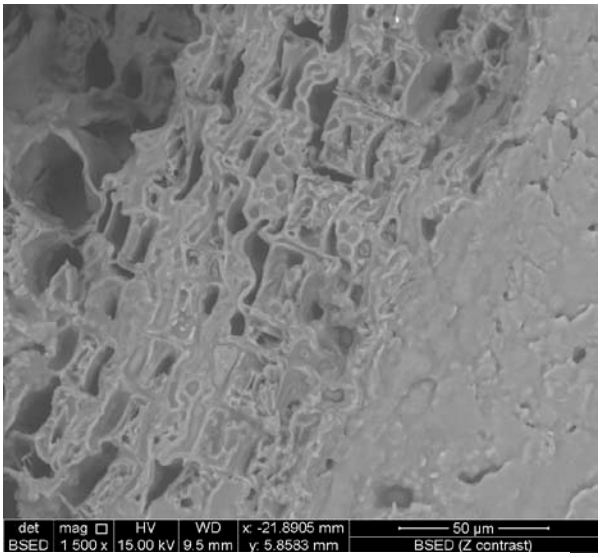

Figure 18. G1RT-N4. A newer material sample, treated at room temperature. The sucrose has deposited much less evenly, with more empty cells.

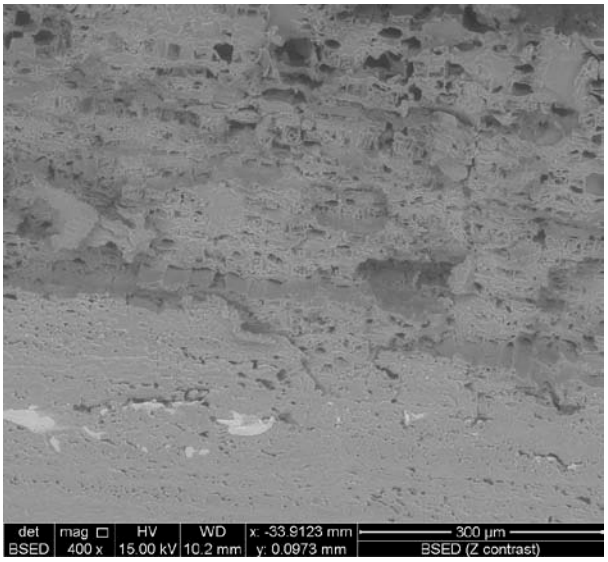

Figure 19 . AET-D4. Artificially degraded sample treated at an elevated temperature

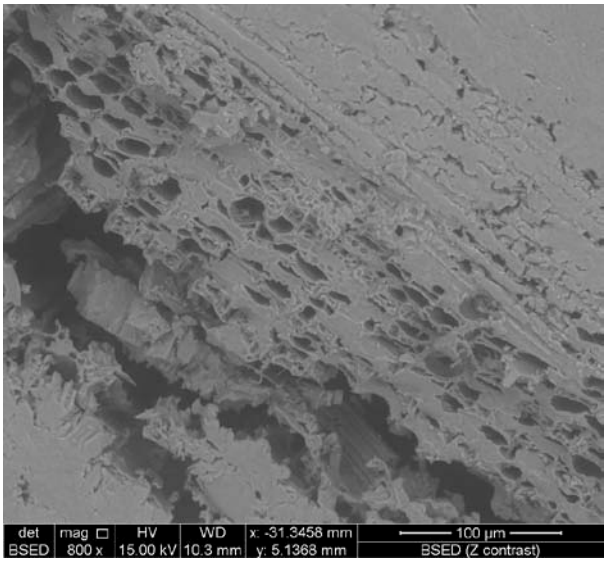

Figure 20. AET-N4. Newer sample material treated at an elevated temperature. Both samples show approximately the same amount of sucrose deposited.

The SEM images corroborate the results gained at the macro level, indicating that the six-month samples retained their shape on a cellular level much better than their four-month counterparts. There was much less cellular collapse and distortion overall. The six-month samples at the macro level had much less overall dimensional change than the four-month

samples. The six-month samples also absorbed more sucrose more evenly across the cells than the four-month samples as can be seen in the example of figures 21 and 22.

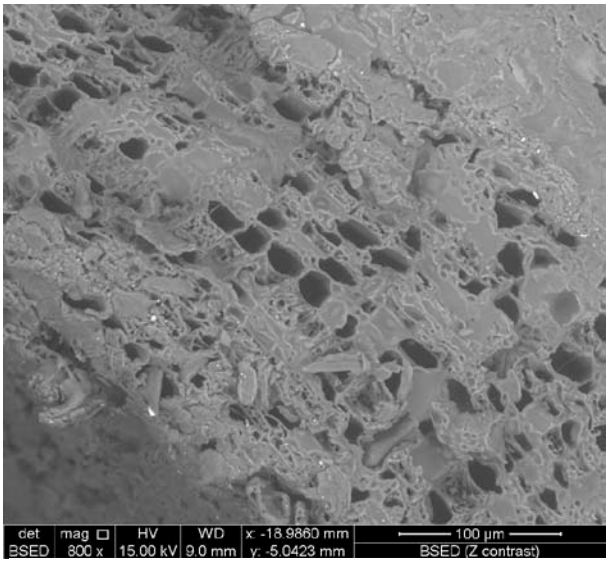

Figure 21. G1ET-N4. Illustrating the distribution of sucrose in the four-month sample

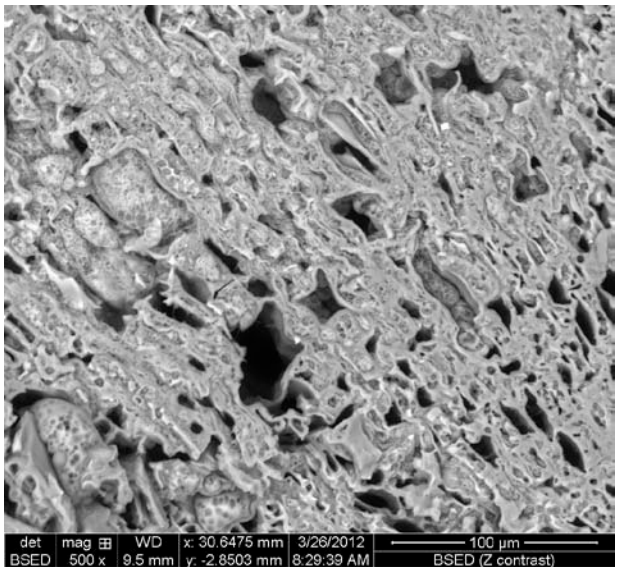

Figure 22. G1ET-N6. Illustrating the distribution of sucrose in the six-month sample given the same method of impregnation as at left.

Conclusion

Based upon the test results, the use of sucrose as an impregnant for waterlogged cedar bark can be successful. The handling properties after treatment were very encouraging: the samples were stable, they were not brittle, their surface was not friable, and they retained some flexibility. The only disadvantage was the darkening of colour caused by the sucrose treatment. This was minimized when the samples were impregnated for a longer period of time although this factor could not be tested on the archaeological materials. After testing the variables of length of time in solution, temperature of the solution, and the speed at which the concentration of the solution was increased the suggestions for treatment are as follows. One should increase the concentration of the solution gradually; the method of increasing the concentration by 10% every two weeks was very successful. One should keep the solutions at room temperature. Mould was a small problem when the solutions were kept at room temperature, but this can be managed by changing the solutions regularly in order to keep mould growth at a minimum. Severely degraded archaeological material may require less time in solution. The handling

properties and appearance of the cedar bark following treatment was quite different from that produced by the PEG treatment. Before cedar bark basketry is treated by this method, one must be sure that the handling properties and appearance match the final outcome desired by the curator or archaeologist for that object. The darkening of the colour may be a significant deterrent.

There are still many variables that should be researched further. The archaeological materials had very good dimensional stability even after only three months in solution and so may not require as long a time in solution as the less degraded materials. Further, there was a significant difference between the four-month results and the six-month results in terms of dimensional stability and colour, longer impregnation times should be tested to determine if there are any differences after eight months. Different adhesives should be tested on the treated materials to determine if their use is possible as a further stabilizing method for fragmentary cedar bark. Experimentation with different solutions of sugars should be undertaken, such as a mixture with Sucrose and Mannitol, to determine if mixtures that have been used to treat waterlogged woods might have better properties for basketry as well.

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