The Effect of Consolidation on the Anatomical Structure of Floated Charcoal Remains at Kaman-Kalehöyük

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ABSTRACT

Four consolidants (Acryloid B-72, Butvar B98, Aquazol 500, Methylcellulose) were applied to ancient charred wood samples in order to determine which consolidant, if any, worked best to preserve and strengthen the charred wood for transport abroad and analysis without hindering the archaeobotanists' ability to determine wood species. Upon consultation with the archaeobotanists, consolidation was done after flotation of charred wood samples, and separately, a small charred log was consolidated to mimic consolidation of charred wood in the field. The samples were transported to the United States where they will be thin-sectioned and analyzed. The results of this analysis will be published at a later date in the *Anatolian Archaeological Studies* XVIIII.

INTRODUCTION

Project Background

The study of plant remains from archaeological sites is known as Archaeobotany. Archaeobotany can elucidate the role of plants in the past by studying their usage for fuel, building materials, medicines, and crops. Until the 1960s, little attention was paid to archaeological plants remains, in part because of the practical difficulty in their recovery from archaeological deposits. Prior to the development of the flotation technique, which is essential to recover charred plant remains from the soil matrix, it was often thought that plant remains did not survive except in destruction levels. (Nesbitt 1995) At Kaman- Kalehöyük in 1992, a Siraf-style flotation machine was built to allow for the processing of much larger amounts of samples. Currently, each season at Kaman-Kalehöyük, archaeobotanical materials are processed, using the flotation machine, by Dr. Andrew Fairbain of Queensland University, Australia, and his graduate students. The overall aims of archaeobotanical field research at the site are to understand the economic and environmental relation of past societies as evidenced by plant remains. (Fairbairn 2007)

With the use of flotation, there is a balance between the benefits and the drawbacks. The main benefit of flotation is its effectiveness in processing large amounts of soil – a wide range of deposits can be processed without slowing down excavation. However, it is also a highly destructive process – many charred remains, for example, may disintegrate on contact with the water, or good-sized charcoal samples may lose a significant amount of volume as a result of going through flotation, resulting in the loss of data. Additionally, charred plant remains are very fragile when dry, making them susceptible to continued damage, post-flotation. The damage of samples may then continue, as flotation samples from Kaman-Kalehöyük undergo further handling as they are packaged and transported to Australia where they are prepared for examination and analysis by the archaeobotanists.

This season, much charred wood, most likely architectural beams, were found at the site, where currently Dark Age levels are being excavated. The conservation team was called out to the site to consolidate posts and a beam (South, Sector LVI6, L3, 48 (87), on Floor 1 of room 155). In conversations between the conservation and archaeobotany teams, questions were raised about how consolidants affect wood charcoal to be used for species identification. Consequently, this study was undertaken with the aim to elucidate if in fact, consolidation of both floated and dry charred wood affects later analysis by archaeobotanists. Specifically, does consolidation distort or interfere with the structure of the wood, hindering species identification? Also, does consolidation help to preserve the wood's anatomical structure during transport, compared to unconsolidated samples?

Archaeological charred wood remains

When wood is burned in an anoxic environment exposed to prolonged heat, charred wood is formed. Charred wood often survives on archaeological sites since it is chemically stable and no longer contains organic constituents that may be appealing to organisms for consumption. Archaeological wood charcoal often provides the most extensive evidence of the past environment. Wood is a commonly used material throughout human history, and was used in buildings, heating, cooking. Some species of wood are more likely to survive carbonization than others, and wood used for fuel will be represented in greater amounts than burned structural remains. Also, certain structural characteristics of wood take on added significance in charcoal identification since other characteristics are obliterated or distorted during the carbonization process. In general, of all the macroscopic traits, pore pattern, which is exists in hardwoods only, is the most reliable characteristic that survives carbonization. Species with distinctive pore patterns, especially the ring-porous hardwoods are easily identified in the carbonized state. (Rossen and Olson 1985) Despite significant deformations of the wood, it's gross anatomical structure and most microstructural elements remain largely intact after carbonization. (Asouti website)

At the site of Kaman-Kalehöyük wood charcoal analysis provides insights into the use of wood resources at the site, the presence of tree taxa in local environments, and woodland composition. (Fairbain 2006) Wood charcoal can represent fuel or burned structural remains, and can usually be identified by genus. The most common species of wood charcoal found at the site are oak and conifer from the Bronze Age, and willow/poplar from the Iron Age/Ottoman Period.

Flotation and its effect on wood charcoal

The process of flotation is based on the simple premise that soil and rocks sink in water, while charred remains, including seeds, chaff, and charcoal float, allowing for archaeobotanical remains to be effectively separated from the soil matrix. In principle all that is needed is a bucket and water, which is usually accessible at an archaeological excavation, however a flotation machine, like the one Kaman-Kalehöyük with a water pump and multiple tanks, allows for faster processing of soil and reuse of water. The main benefit of the use of flotation for the processing of archeological plants remains is that a large volume of soil can be processed and plant remains collected with reasonable effectiveness. The main drawback is that many charred remains are destroyed in the process, taking any information with them.

Flotation causes destructive mechanical stress on wood charcoal that leads to fragmentation and loss of plant material. First, impact stress affects the charcoal as it hits the water, and secondly, internal stresses, which can cause further breakdown as the charcoal dries out and moisture gradients begin to develop from the outer layers to the inner core. With flotation, there are a greater number of samples, but they are significantly smaller in size. Sample size of at least 4mm is required for species identification. Additional stress is placed on the wood charcoal samples, when they are transported from Turkey to Australia for analysis at the end of the season, further limiting their chances of being useful in archaeobotanical research.

Consolidation and Consolidants

In conservation, consolidation refers to a generic group of conservation treatments, including surface consolidation, mechanical consolidation, impregnation, and chemical stabilization. In common use, consolidation is defined as a process of solidification or joining into a single unit, with the purpose of stabilization. (Rowell and Barbour 1990, p.302)

For the consolidation of wooden objects, a number of consolidants have been used, most commonly including Acryloid B-72, Butvar B98, Butvar B90, Polyethylene glycol (for water-logged wood), and Klucel G.

In previous studies, Barclay (Barclay, 1981) brush applied 5% Butvar B90 in ethanol to slightly degraded parts of an 18th century wooden fire engine and found the surfaces smoother and better to withstand surface cleaning. He also found that with the parts of the fire engine easily removed, through vacuum impregnation they were able to be consolidated with 10 times more consolidant than through brush application. In 1987, Hatchfield and Koestler investigated the re-treatment of an Egyptian wooden object previous consolidated with paraffin wax. They found that when wood samples, both previously treated with paraffin wax and not, were soaked in 5% B-72 in toluene there was good preservation of surface characteristics of the wood, and distinguishing features of wood anatomy were preserved, while substantial detail was obscured. (Hatchfield and Koestler 1987) In 2001, Spirydowicz et al. tested the consolidation of wood samples by vacuum impregnation of with varying concentrations Butvar B98 in 60:40 ethanol and toluene. Analysis of these samples with scanning electron microscopy showed that a vacuum impregnation treatment of decayed archaeological wood with 10% Butvar B98 can be carried out without significantly altering the micromorphological structure of the wood. Scanning electron microscopy was also used by Schniewind and Eastman in 1994 to determine the distribution of the vacuumed impregnated consolidants Butvar B98, Acryloid B-72 (20% in acetone) and Butvar B90 (5% in 40:60, ethanol and toluene and 20% in ethanol) in deteriorated wood samples. They found all consolidants to be unevenly distributed and more concentrated at the surfaces of the samples. In a study most relevant to the current one, on the consolidation of charred wooden sculptures, Constance Stromberg tested Acryloid B-72 and Butvar B98. She applied varying concentrations of both consolidants to charred wood samples by syringe and brush after the test surface had been pre-wetted with ethanol to determine which consolidant was best suited for the treatment of charred wooden structures in-situ, in a church in Quito, Ecuador. Immersion in consolidants, like in the case of the current study, was not feasible due to the dissolution of carbonized wood in all solvents. She found that while Acryloid B-72 likely penetrated better, the viscosity of Butvar B-98 was desirable in the case of this treatment as the wooden sculptures were at acute angles inside the church. (Stromberg 1999)

For consolidation treatments of works of art, the ideal characteristics of a consolidant include imparting sufficient strength to the object so it can be handled and cleaned safely, provide appropriate structural strength, flexibility and hardness, not creep, maintain stable mechanical properties with age, not discolor with age, be non-toxic, and be affordable and reasonably easy to apply. (Barclay 1981, p.135) Also, typically with the conservation of wooden objects while it is accepted that the wood may darken, a high level of gloss is not desirable. While some of these characteristics are desirable in the case of this study, others, like aging and aesthetic properties are not relevant, as the charred wood samples will be thin-sectioned and mounted in resin on glass slides for analysis.

How might consolidation, with materials typically used in conservation, help preserve archaeobotanical samples? Ideally, consolidation would occur prior to flotation, but as pointed out by the archaebotanists at Kaman-Kalehöyük, this is not feasible, because the purpose and main benefit of doing flotation is that one does not have to take the time to go through by hand in the soil and pick out large pieces of charcoal. So the question becomes does consolidation, if it is done after flotation, help preserve the anatomical structure of the wood charcoal in addition to strengthening the charcoal to survive a trip overseas at the end of the season? Separately, what affect does consolidation of charred remains in the field have on the anatomical structure of the wood charcoal? In the currently study, Acryloid B72, Butvar B98 were chosen to use as consolidants due to their extensive past use in conservation for the consolidation of deteriorated wood. Aquazol 500, Methylcellulose were also included in the study since they are commonly used in conservation, water soluble, which makes them easy to prepare in the field, and are relatively non-toxic. They could also be used to consolidate the floated charred wood samples while still wet.

EXPERIMENTAL METHODS

Experiment 1: Flotation/Consolidation

In this experiment, four consolidants (Acryloid B72, Butvar B98, Aquazol 500, Methylcellulose) were applied to samples of wood charcoal which have undergone flotation, in order to determine what effect, if any, post-flotation consolidation has on

Consolidants tested	Carrier solvent	Number of samples
5% Acryloid B72	Acetone:ethanol (3:1)	3
10% Acryloid B72	Acetone:ethanol (3:1)	3
2.5% Butvar B98	Ethanol:toluene (4:1)	3
5% Butvar B98	Ethanol:toluene (4:1)	3
5% Aquazol	Tap water	3
10% Aquazol	Tap water	3
0.5% Methylcellulose	Tap water:ethanol (1:1)	3
1% Methylcellulose	Tap water:ethanol (1:1)	3
Wet control	N/A	3
Dry Control	N/A	3
Total number of samples		**30**

Table 1 **Types of consolidants and number of samples used in the experiment**

preservation of the anatomical structure of wood and thus the archaeobotanist's ability to determine wood species.

Sample Preparation

The charred wood used in the experiment was removed from the site by the Conservation Team, from charred Log 3, which dates to the 10th century B.C. and had not been consolidated in the field. (South, Sector LVI6, L3, 48 (87), on Floor 1 of room 155) Charred wood removed from Log 3 ranged in size and was stored in polyethylene boxes, to keep moist, for two weeks until the experiment was run. To create samples for the experiment, the charred wood was cut with a #11 scalpel and also broken by hand into pieces in the lab. An effort was made to create equal-sized samples, however this was challenging as the charred wood tended to crumble upon handling. In total, 30 samples were taken - 24 test samples, 3 wet controls, and 3 dry controls. The samples were weighed prior to flotation. After weighing, the samples were stored in a plastic tray which was placed in a polyethylene bag for one day, in order to prevent drying. The samples were transported to the flotation tank in the same plastic trays to carry out the experiment.

Flotation

In order to simulate the treatment of charred wood samples by archaeobotanists, each of the experimental samples and the wet controls were run through the flotation tank at Kaman-Kalehöyük. The method for flotation was as follows. Each sample was run individually through flotation with 350ml of soil for 2 minutes. The soil and sample were dropped into the tank, and if the charred wood sample floated to the surface immediately, it was left to sit in the uppermost tank for the 2 minutes. After two minutes, the sample was retrieved by hand and placed back in its tray. If the charred wood sample did not immediately float to the surface, the water was agitated, as is normally done by archaeobotanists during flotation, until the 2 minutes passed, and then the sample was retrieved from the water by hand and placed back in its tray. Since the charred wood samples were quite large, none of them were pushed over the edge of the tank into the collection bucket.

The charred wood samples to be consolidated with Acryloid B72 (5%, 10% in acetone:ethanol (3:1)) and Butvar B98 (2.5%, 5% in ethanol:toluene (4:1)) were floated and then left to dry in the Conservation lab in a plastic tray for 24 hours prior to consolidation. The charred wood samples to be consolidated with Aquazol (5%, 10% in tap water) and Methylcellulose (0.5%, 1% in tap water:ethanol (1:1)) were dried in the Conservation lab for 2.5 hours and were then consolidated while still wet.

Consolidation

Each sample was weighed before consolidation. With the sample on the scale, consolidant was added dropwise. A ratio of sample weight to consolidant weight was used to ensure equivalent amounts of consolidant were added to each sample since the samples were not uniform in size. One third of the weight of the sample was the amount of consolidant subsequently applied dropwise to the sample. This ratio was determined by adding consolidant to the first sample dropwise until the sample did not absorb more consolidant; the weight of consolidant absorbed by the first sample was found to be one third the weight of the sample. Samples were oriented longitudinally when applying the consolidant in order for it to more likely to fill the vessels. An effort was also made to apply consolidant to all surfaces of the sample. The weight of wet consolidant added was recorded. Samples were left to dry completely in the lab and their weight was recorded once dry. The samples were placed in polyethylene bags for storage. All consolidant solutions were made weight to volume, consolidant to solvent.

"IN-SITU" CONSOLIDATION

Sample preparation

A small, charred log also dating from the 10th century B.C. was removed from Room 157, (Small find #1, South, Sector LVII, Grid L350, Quadrant (71), Provisional layer 40) by the Conservation team. It was wrapped in plastic sheeting and stored in the Conservation lab for 3 weeks prior to consolidation. During this time the log had fragmented a significant amount but was still usable for the experiment. The log was kept intact, moved to a plastic tray, and four sections were delineated by purple painter's tape (Duck products, U.S.A.). A control sample was removed prior to consolidation.

Consolidation

Each of the four sections of the log were consolidated dropwise with 7ml of one of the following consolidants: 5% methylcellulose (in tap water:ethanol (1:1)), 10% Acryloid B72 (in 3:1, acetone:ethanol), 5% Aquazol 500 (in tap water), and 2.5% Butvar B98 in ethanol and toluene.

SAMPLE PACKAGING AND TRANSPORT

All of the wood charcoal samples were packaged for transport to the United States in polyethylene bags, set within polyethylene boxes, with cotton wool added for padding. Masako-san brought the packaged samples to the Kırşehir Museum to ask for permission to bring the samples to the United States.

PROCESSING OF SAMPLES AND INTERPRETATION OF RESULTS

The processing and interpretation of results is to take place in the United States. The author is in contact with Dr. Andrew Fairbain and various faculty members at the University of Delaware Microscopy Center, where she currently attends graduate school in order to arrange for thin-sectioning of the samples. After visual analysis of the thin sections is undertaken, the results of this study will be published in the next volume of Anatolian Archaeological Studies.

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