The Reburial of Waterlogged Archaeological Wood in Wet Environments

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ABSTRACT

Reburial has good potential for long-term preservation of waterlogged wood in wet environments. The scale and significant conservation problems of archaeological wood from shipwreck sites makes this issue of paramount concern to the field of maritime archaeology. A review of projects since the 1980s where reburial monitoring or reburial experiments have taken place provides insight into alternative methods and their potential for success.

Introduction

Shipwreck sites dominantly consist of waterlogged timbers, and the sheer volume of wood causes significant problems of time and money for standard conservation measures. The issue of reburial as a long-term preservation strategy and its effectiveness is of utmost importance to the field of maritime archaeology. Reburial, as used here, involves the deposition of archaeological materials beneath sediments in a marine or wet environment in an effort to create anaerobic or anoxic conditions that inhibit the growth of bacteria and limit other harmful organisms. Systematic monitoring of reburial sites is of the highest importance for all in situ preservation treatments because the archaeologist or conservator cannot fully predict the long-term suitability of the reburial context.

Agents of Deterioration for Waterlogged/Submerged Woods

Wooden items are mainly comprised of cellulose, hemicellulose, and lignin. Wood is one of the most resistant organic materials and can be preserved for long periods under cold, wet, dry, or anaerobic conditions (Hedges 1990:111–140; Robinson 1998). Submerged wood is susceptible to deterioration by marine woodborers, marine burrowing activity, marine fungi, marine bacteria, and water movement caused by various processes. Usually soft rot fungi are found in completely submerged archaeological wood (Blanchette et al. 1990:144–174; Björdal 2000). Soft rot fungi generally occur when the temperature falls to 0º C and between 60º C and 62º C, which, in the latter case, are known as thermophiles. Soft rot fungi tolerate various levels of oxygen and pH but are able to attack wood at oxygen levels too low for white rot or brown rot fungi. Soft rot fungi also have been found tolerant to varying pH levels (Grattan 1987:55–67; Blanchette et al. 1990:144–174).

Bacterial degradation of wood often operates in conjunction with fungal attack. There are three main types of marine bacteria—tunneling bacteria, erosion bacteria, and cavitation bacteria. Erosion bacteria are very dangerous to waterlogged archaeological wood because they have adapted to survive at extremely low oxygen levels. Tunneling bacteria are found in some samples of wood during reburial studies (Blanchette et al. 1990:144–174; Nilsson 1999:65–70).

Two additional agents for the deterioration of waterlogged archaeological wood are degradation by marine woodborers and marine burrowing activity. Woodborers in the marine environment include mollusks such as *Teredinidae* (shipworms) and *Pholodaceae* (piddocks) as well as crustaceans, including *Limnoria* (gribble), *Sphaeromatidae,* and *Cheluridae* (Gareth Jones and Eltringham 1971; Pearson 1987). *Teredinidae* require at least 12% salinity for normal development and are restricted to 200 m in depth, while *Pholodaceae* have been discovered in depths of up to 2,000 m. *Limnoria* are limited from 15% to 18% salinity and can live in depths up to 530 m (Grattan 1987:55–67; Pearson 1987). All marine woodborers are restricted by oxygen content.

Reburial Studies and Experiments

Reburial of saturated wood as a preservation strategy has a lengthy history, both in a practical sense and in experimental work assessing its efficacy. Basic early attempts at reburial occurred in Holland where wrecks uncovered in the Polders were removed and reburied offshore past the low tide mark to ensure a more constant water depth (Björdal and Nilsson 1999:75). A second long-standing burial approach is the use of a "sediment drop" strategy. Here exposed wrecks or waterlogged woods are blanketed with sediment dropped from the water surface to provide a protective cover. Large areas of a site can be treated at once, but the sediments can disperse outwards. There is a risk of damaging or contaminating the archaeological deposits with the force of the drop. Backfilling an excavated archaeological site with the original overburden of sediments and ballast also has been performed often, but this method rarely provides an impermeable barrier to marine organisms and oxygen (Oxley 1998:159–173).

Practical and experimental studies of reburial have been undertaken in several different contexts involving various species of wood, different types of sediments, and varying depths. As reviewed in Table 1, these studies generally include concerns for reburial efficacy, environmental monitoring of reburial deposits, laboratory simulation of reburial environments, and examination of modern woods and their preservation properties. Specific findings vary, but there is general agreement that the reburial of archaeological material has the potential to be a cost-effective method of preserving saturated woods in situ. A brief review of a small number of substantive projects relating to reburial environment, archaeological and modern wood preservation, and environmental monitoring provides critical observations for formulation of a reburial preservation strategy.

A major reburial experiment using archaeological and modern wood was conducted by Parks Canada on a Basque whaling vessel in Red Bay, Labrador (Waddell 1994) <*http://www.pc.gc.ca/progs/pfa-fap/index_e.asp*>. Here, archaeologists disassembled and documented more than 3,000 timbers and fragments from a fully excavated wreck, after which reburial was carried out in the excava-

Table 1. Summary Review of Select Reburial Projects and Experiments

Project Name/Topic	Experiment/Summary	Reference
Testing archaeological soils for preservation	Using soil chemistry to determine the efficacy of reburial as a conservation method.	Hunter 1980
Conservation through reburial	Theoretical text exploring the conservation of archaeological sites and artifacts through reburial.	Gonzalez and Mathewson 1988
Conservation through reburial	Study of the factors that affect the preservation of artifacts during reburial through the examination of waterlogged archaeological sites.	Oxley 1990
Conservation through reburial	A further study of the factors that affect the preservation of artifacts during reburial through the examination of waterlogged archaeological sites.	Oxley 1992
Parks Canada, Red Bay, Labrador	Experiments with both archaeological and modern timbers and reburial environment.	Waddell 1994
Duarte Point wreck	Interim discussion of the experiments of reburial and material corrosion and decomposition conducted on the Duarte Point wreck.	Gregory 1995
Modern wood experiments	An investigation of reburial and in situ preservation possibilities conducted with modern wood samples.	Oxley 1998
Lynæs Sands, Denmark	Study of reburial including modern wood and burial test fabric, incorporating environmental monitoring and sediment analysis.	Gregory 1998
Nydam Mose	Experiments with modern wood samples, also incorporating environmental monitoring.	Gregory et al. 2002
Harbor of Marstrand	Long-term experiments using modern wood samples of three different types.	Björdal and Nilsson 2003

tion pit. Timbers were stacked in three layers with 20 cm of sand above each layer. The researchers surrounded the timber and sand mound with 36 metric tons of sand contained within 1,200 recycled plastic salt bags. Rock fill was placed outside of the sandbag circle, and a 36 mm Hypalon tarpaulin was positioned over the mound and held down by 60 concrete-filled tires. Water-sampling tubes were installed so that water chemistry could be tested inside the mound without disturbing the fill strata. Researchers also used frozen samples of wood and wood suspended in the open water column as control groups (Waddell 1994:3). One year after sealing the mound, the dissolved oxygen level fell to 1 mg/liter and has held constant. The dissolved oxygen of the water around the mound has tested from 9 to 10 mg/liter consistently. Other chemical properties tested include sulfide, alkalinity, pH, nitrate, ammonia, nitrite, total phosphorous, silicate, and iron. These tests have illustrated that the reburial environment is a reducing one (Waddell 1994:4).

David Gregory (1998) carried out experiments with wood burial at various depths in the sandy sea bottom of Lynæs Sands, Denmark. Fresh samples of radially split sapwood oak planks were divided into three groups: the first left exposed to seawater, the second buried just below the surface of the sediments, and the third buried 50 cm below the surface of the seabed. Gregory placed a Shirley Soil Burial Test Fabric next to the wood to assess the cellylolytic microbial activity because of the short-term nature of the experiment. This fabric is 96% cellulose and, although there is no lignin, provides a good indication of the presence of cellulose-degrading microorganisms. The specimens were examined at 4-week intervals up to 16 weeks and then again at 32 and 52 weeks. In addition to test samples, the environment was monitored for dissolved oxygen content, pH, redox potential, ammonium, and nitrate. These experiments indicated that the dissolved oxygen content of the sediment rapidly decreased with increasing time at both burial depths and the redox potential at both depths became increasingly negative. There was almost no variation in pH, and the ammonium decreased and stabilized just below the seabed. Nitrate content increased in surface and shallow burial samples, suggesting oxidizing conditions, but decreased at 50 cm, indicating that conditions were moving towards an anaerobic environment. This experiment shows that the burial of oak specimens at a depth of 50 cm in sand is conducive to preservation of oak and the Shirley Test Fabric (Gregory 1998:343–358).

Charlotte Björdal and Thomas Nilsson (1999) similarly conducted experiments on reburial sediments and their impact on modern wood within a laboratory environment. The authors placed fresh wooden stakes in plastic boxes containing clay, sand, and a control sediment in order to detect any differences in microbial aggressiveness among sediments. They also used different cover techniques, including geotextiles and sawdust. The authors measured the test stakes after three, six, and nine months by weight-loss measurement and light microscopy. They concluded that there was no real difference in decay after nine months of burial in sand or clay (Björdal and Nilsson 1999:75).

Following up on the previous study, Björdal and Nilsson (2003) tested the reburial environment around the Swedish shipwreck *Fredericus* <*http://www.svk.com/reburial*>. They mounted three groups of samples on a plastic rack next to the wreck, each group including one sample of oak, pine, and birch. Samples were placed on the surface and buried at depths of 13 cm and 43 cm. Decay from soft rot fungi and tunneling bacteria was observed in all wood samples exposed above seabed after six months but not in the buried samples. After 12 months, marine borer degradation was found to occur in all exposed samples, while those buried at 13 cm had soft rot fungi, tunneling bacteria, and erosion bacteria. In samples buried at 43 cm, the authors found only erosion bacteria (Björdal and Nilsson 2003:2–3). This study also illustrated that different wood types react differently to soft rot fungi, bacteria, and marine borers. Pine was more susceptible to marine borers than oak and birch; oak was more susceptible to soft rot fungi; and pine and birch were more susceptible to tunneling bacteria (Björdal and Nilsson 2003:4).

Toward a Preliminary Strategy for Saturated Wood Reburial

Experimental studies to date suggest the ideal reburial environment for waterlogged archaeological wood and other cellulose-based organic archaeological materials to be at a depth of more than 50 cm in fine-grained sediments such as silt, clay, or sand. While initially the dissolved oxygen content is higher than in large-grained sediments, a quickly reducing environment occurs. Nitrogen levels should be kept as low as possible because an increase in nitrogen facilitates increase in the soft rot fungi attack rate. Less important is pH, as varying pH levels have limited effect on soft rot fungi.

Geotextile blankets are further recommended as a stabilizing cover over reburied remains. Geotextiles are synthetic fiber products that prevent sediment erosion or act as a sediment and liquid filter, dependent upon the weave of the fibers. Conservators employ smaller geotextile covers to protect smaller items for storage or reburial (Björdal and Nilsson 1999:75). As was carried out in the Parks Canada Red Bay project, a very large geotextile tarpaulin can be effectively used to blanket and stabilize an entire reburial site (Waddell 1994:2).

In most cases, environmental and site monitoring is critical. Requirements will vary from site to site, but water quality parameters needing to be monitored generally are temperature, pH, dissolved oxygen, redox potential, and electrical conductivity. The monitoring device must be able to test repeatedly in a nondestructive manner over a long period. The installation and maintenance of the monitoring device should involve minimal disturbance to the archaeological deposit, and the device itself should be resistant to the marine environment and have the option for continuous automated sample collection and data storage (Waddell 1994:2–4; Davis 1998:21–25). Piezometers, such as a standpipe or a dipwell, are often used because they respond quickly to changes in compaction. Two other commercially available moisture-measuring devices that permit long-term repeated and nondestructive measurements at the same location are electrical moisture cells and the neutron probe (Davis 1998:21–25).

It is clear that the reburial of saturated archaeological wood is a viable in situ preservation measure when used correctly and with proper monitoring and planning. Further experimentation carried out with both archaeological and modern organic material will be invaluable to advancing this form of passive conservation.

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