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WOOD IN ARCHAEOLOGICAL RESEARCH

Professor **Karl Borgin,** *AINA's Adjunct Professor of Wood Sciences, received his university education from the Universities of Oslo (Norway), Uppsala (Sweden), and Stellenbosch (South Africa). He has done post-graduate studies at the Universities of Cambridge and Leeds (U.K.) and Wisconsin in Madison (U.S.A.)*

Born in Oslo, Dr. Borgin went to school there, took part in the resistance movement during the war, and has spent most of his time since 1953 outside Norway.

Educated as a polymer chemist, he has devoted most of his research to wood chemistry, which he has also taught at several universities. For many years, he served as Head of the Wood Chemistry Section at Stellenbosch University, visiting professor at Hamburg University in 1974, and is currently Professor of Wood Chemistry at Thesaalonìki University in Greece, at the invitation of the Greek Government.

His connection with archaeology stems from interest in the problems of the durability of materials and their resistance to deterioration. Being a Norwegian and an expert on wood, he naturally turned to the study of wooden ships, and the famous Viking ship in Oslo was one of the first he investigated. He even developed a method, together with Professor Parameswaran of Hamburg University, to determine how sharp the axes were which the Vikings used to shape the planks of their ships!

His interest in ancient wooden ships one day led him to AINA, and in 1974 he drove his Volkswagen camper from Oslo to Bodrum, Turkey, to join George Bass there.

He has for several years been working on a new process for preserving and conserving water-logged wood, and for this reason, he was invited to Thessaloniki University to continue the work. He hopes to complete the fundamental part of the work this year, and if successful, he hopes the Thessaloniki process (as he likes to call it) will be used to preserve and restore future salvaged wooden hulls. The process has worked perfectly in preserving wood which was water-logged for 100,000 years from an inter-glacial period in Scandinavia. He consequently sees no reason why it should not work with a ship that is "only" a few thousand years old.

To introduce AINA members to his work, Dr. Borgin has prepared the following article.

Karl Borgin

Wood for Ships

The importance of wood in archaeology lies in the fact that wood has always been used as a material for tools, implements, buildings and other structures. It is older than any other material used by man, older than metals, pottery, and ceramics. With the development of metals, wood was not abandoned but used simultaneously with other materials. Wood is unique in this respect, and during any archaeological period wood was used for a number of purposes.

With the exception of some types of boats built from reeds and animal hides, wood has always been the main material for the construction of boats and ships of all sizes. Wood, therefore, occupies a special position in nautical archaeology, and much of the work that has been done on preserving and conserving old wood has been done in the field of nautical archaeology with waterlogged wood. Nautical archaeology is in a unique position, since sunken ships represent archaeological finds which have not been disturbed by man nor robbed for treasures. This situation unfortunately is changing rapidly due to the large number of amateur divers who, without the necessary skill, raise parts of ships and their contents and therefore destroy much of their value to archaeology. Nevertheless, when a ship is undisturbed by man, the damage that exists is the result of natural agencies, the slow deterioration caused by sea water, bacteria, and fungi.

Natural Durability of Wood

Wood is inherently a very durable material, but because it is made of organic materials composed of carbon, hydrogen and oxygen, wood is a food for many types of micro-organisms and certain insects. The durability of wood is therefore limited by the fact that it is biodegradable,

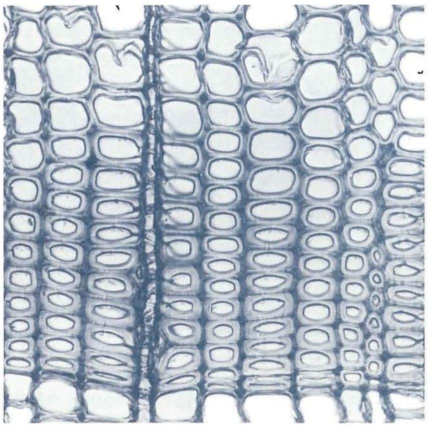


Fig. 1
Microstructure of new, intact pine.

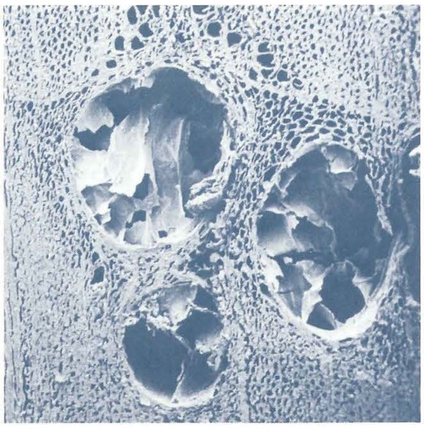


Fig. 2
Microstructure of well-preserved oak from the Viking ship in Oslo, Norway.

but wood will also slowly deteriorate due to the action of water and oxygen. The main component of wood, cellulose, is a polymer carbohydrate and can therefore be used by a number of micro-organisms as a source of energy. Bacteria and fungi use enzymes to break the polymer cellulose into sugars and use them as food. The second component of wood, lignin, can also be degraded by micro-organisms, but with greater difficulty. (Fig. 1.)

The first component of wood to break down is cellulose, later followed by the deterioration of lignin. When wood is exposed to water for a considerable length of time, a slow hydrolysis takes place, which causes the fracture of the cellulose molecule into simple sugar. This process is extremely slow, and the physical strength of the wood is not very much affected by exposure in an underwater environment. Oxygen also slowly oxidises cellulose and forms compounds which are less stable than cellulose with an accompanying loss of mechanical strength, but this is also a process that takes a very long time.

If wood is exposed to strong light, the chemical effect of ultra-violet radiation becomes important. The effect of photochemical processes, however, is not very serious, since the breakdown of the wood structure is limited to the surface of the wood and does not normally penetrate more than a few millimeters.

When wood is exposed to the effect of the weather and the combined effect of oxygen, water, light and microbiological breakdown, the process is normally referred to as "weathering". If, however, wood is protected from the direct influence of light, water and other elements of the atmosphere, the process is given the more general term of "aging". The rate of deterioration, whether by weathering or aging, depends very much on the environmental conditions under which the wood is stored.

Under certain conditions the breakdown and deterioration of wood can be very rapid indeed, and only a couple of years are required to break down completely even large pieces of wood used in buildings and other structures. However, under other conditions, wood can be extremely stable and can actually last for centuries.

There are basically three different environmental conditions which are favourable for the durability of wood. *One condition* is represented by a very dry atmosphere, constant temperature and no light. Such conditions are often found on archaeological sites. Good examples are wood found in the inside of pyramids in Egypt. We have examined in our laboratories wood from three different pyramids in Egypt. One of them was an Acacia, another was a Pinus, and the third was a Juniper, and this wood was found almost intact. The chemical composition and the anatomical and submicroscopic structure of these woods were practically those of new wood. Very little deterioration had taken place during a period of up to 4000 years.

Some breakdown of the cellulose components had taken place, and a certain change in the lignin molecule was also observed by spectroscopic investigations. The changes were, however, too small to affect the strength properties of the wood and had no serious consequences for the durability of the wood as an archaeological material.

The second condition is quite different and consists of exposure to weathering in cold climates at high altitudes. Such conditions are found in countries like Norway where wooden buildings exposed to such an environment may last for hundreds of years without any real deterioration. We have investigated wood from old buildings in Scandinavia and found that the mechanical and chemical properties have changed very little. The main changes of the wood from these old buildings had only taken place on a very thin layer on the surface of the wood. However, due to repeated wetting and drying of the wood, mechanical deterioration in the form of cracks had taken place over this long period, but this had little effect on the strength of the wood used in the various types of buildings we investigated.

A third condition is found when wood is completely immersed in water. Such wood is often referred to in archaeology as waterlogged wood. This applies to ships that have sunk and are lying at the bottom of the sea, often covered by mud or deposits of various types.

A special case of waterlogged wood is the type of wood that has been kept in soil which is permanently wet. This was the case with the famous Viking ships found in Norway which had been buried in a type of soil which kept the wood perma-

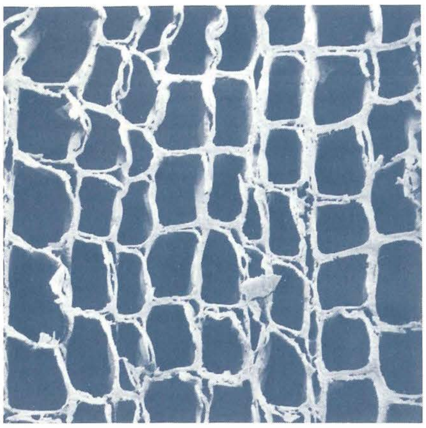


Fig. 3
Microstructure of sound, practically intact pine from a wooden spade used during the Celtic period in Norway.

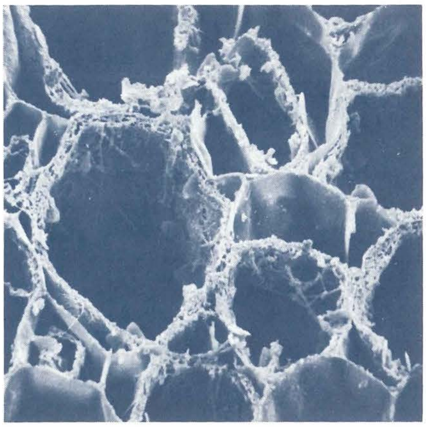


Fig. 4
Microstructure of wood deteriorated by attack from fungi after salvaging and storage on land. Roman ship, Bodrum, Turkey.

nently wet and protected it from bacteria and fungi because of the nature of the soil.

The wood from Viking ships, which we also have investigated in our laboratories, was found to be practically intact, and only part of it had been ruined by microbiological activities. Most of it was as good as new.

Pieces of oak from the famous Viking ship of Oseberg in Norway had strength properties almost identical to that of new wood, and its anatomical structure had changed very little during the 900 years it had been buried. (Fig. 2.)

Similar results were obtained from wooden implements which had been buried in wet soil containing a large amount of clay. This wood was 2000 years old and originated from the so-called Celtic period, long before the time of the Vikings in Norway. This is an example of how waterlogged wood under certain conditions can last very long indeed when microbiological activity is eliminated. (Fig. 3.)

Of special importance for the preservation of wood in old ships is the fact that if the ship sinks in deep enough water, the amount of oxygen is so small that the growth of various micro-organisms is inhibited. If at the same time the wood is protected from other organisms by deposits of soil, mud or sand, the possibilities for excellent preservation of old ships are there. Such ships have been found in excellent condition, and one of the best examples is the Kyrenia shipwreck, excavated by AINA Vice-President Michael L. Katzev.

The Mechanism of Aging and Deterioration

In order to develop methods for preservation and conservation of old, especially waterlogged wood, it is important to understand in detail the mechanism of the aging and deterioration of wood under various environmental conditions. We have therefore during the last few years carried out extensive research on how wood breaks down under various conditions. For this purpose we have studied wood that was found in the pyramids of Egypt, in Viking burial grounds in Norway, and at the bottom of the Mediterranean sea, as well as wood exposed to the full effect of weathering in cold and hot climates. We have studied wood which has been exposed to different types of natural weathering and aging conditions. We have also studied wood which has been exposed to various experimental conditions in hot climates in South Africa and in cold climates in Norway. This has been included in the investigation to study the effect of specific climates on the breakdown of wood.

This research is being carried out in South Africa, Norway and England as well as Germany, with close co-operation between scientists at wood research institutes in these countries. The project is therefore of international character, and the findings are of importance for the conservation and preservation of wood world wide. Research on the changes of the structure and ultrastructure of wood is carried out by using transmission and scanning electron microscopes, while chemical changes during aging are studied with the use of chemical analysis and ultraviolet and infra-red spectroscopy.

Based on this research we have come to the following conclusion concerning the mechanism of the breakdown of wood under different conditions: when wood is stored dry and at constant temperature, the only breakdown in wood structure is a slow oxidation of the lignin and the cellulose components. There is practically no visible changes in the appearance of the wood and its mechanical strength properties remain intact over many thousands of years. When the wood is exposed to the effect of weathering, the breakdown of wood is the same in cold and hot climates, but the rate of deterioration is quite different. In dry, cold climates there is very little microbiological activity and the wood can last very long. A slow hydrolysis and oxidation of the wood components, and mechanical erosion of the surface take place. This can be very slow indeed, and even after thousands of years under favourable conditions, the wood is still in very good condition.

However, there is a continuous breakdown of the important part of the wood structure referred to as the middle lamella, which results in the loosening of fibres from the bulk structure of the wood. At the surface such fibres will be eroded away and there will be a slow mechanical failure of the bulk structure of such wood. Under conditions with high temperature and humidity, the weathering processes as such do take place faster than in cold climates, and under such conditions microbiological activities take place with a rapid deterioration of the wood due to the enzymatic activities of fungi and bacteria.

Under these conditions wood is not durable at all. Some fungi and bacteria will attack the cellulose while others may attack the lignin, but the result is a complete disintegration of the wood tissue, a complete loss of mechanical strength and a total failure of the wood as a structural material. When wood is kept under water like wood from a sunken ship, it can under some conditions be very durable if the conditions are unfavourable for microbiological activities. Hydrolysis and oxidation processes are very slow and, if the ship is in deep water, the attack from fungi and bacteria is even slower.

It is extremely important, however, for the preservation and conservation of such waterlogged wood that when the wood is removed from the conditions under which it has survived for a very long time, the environment should not be changed in such a way that fungi and bacteria find improved living conditions. Otherwise after a few months the microbiological breakdown of the wood would be greater than the deterioration that took place over a thousand years under water. (Fig. 4.)

For preservation and protection of waterlogged wood there are two requirements: The first is to protect the wood from the moment it is removed from the sea water until it has been treated for permanent restoration, and the second is to find methods which can be used to preserve, conserve, and reinforce wood so it can be stored for exhibition.

Preservation and Conservation of Archaeological Wood

The ideal treatment of archaeological wood must fulfill a number of requirements of which the following are the most important:

(1) It must prevent microbiological and any other biological decomposition of wood in the critical phase when wood is moved from one environmental condition to another, (e.g. when waterlogged wood is stored before restoration can take place.)

(2) It must permanently protect wood against any microbiological and biological decomposition after the wood is restored. (e.g. permanent exhibition in museums.)

(3) It must stabilize and protect wood against the detrimental effect of the environment which is non-biological in nature such as variation in humidity, temperature and light.

(4) It must reinforce and strengthen the wood structure especially in the case of archaeological wood which already has deteriorated so far that the wood is physically weakened.

At the moment it is not possible to accomplish all the functions above. A number of treatments have been used, especially immersion in potassium-aluminium sulfate or polyethylene glycol. The first method was used to treat the famous Viking ships restored at Oslo in Norway, and the second method was used to treat the well-known Vasa shipwreck in Stockholm and the interesting ship restored at Kyrenia. The method of treating waterlogged wood with polyethylene glycol is effective, but cumbersome to use, and this treatment has a detrimental effect on the aesthetical appearance of ancient wood of archaeological value on exhibit.

I am of the opinion that none of the present treatments is fully satisfactory. We have therefore for several years been working on a new method which will fulfill all the requirements mentioned under points 1 — 4. This work is done in international co-operation with several institutions like the American Institute of Nautical Archaeology. The chemical and structural part of the investigation has been carried out at Oslo, Norway; Hamburg, Germany; Stellenbosch, South Africa; and is currently being done at the Laboratory for Forest Utilization at the University of Thessaloniki in Greece. If we are successful with the new *Thessaloniki Process* (which we have termed this method), archaeological wood will be treated more effectively and cheaper in the future.

—*Karl Borgin*

Current Field Projects

Survey in Sicily

In March and April, George Bass, Donald Frey and Robin Piercy conducted a survey for ancient shipwrecks around western Sicily. Working in conjunction with Sub Sea Oil Services S.p.A. of Milan, a major Italian diving firm, the team inspected a number of known sites near Trapani, Palermo, the Egadi Isles, and the island of Ustica. Although all of the sites had been stripped of visible cargo over the years by amateur divers, it was hoped that one or more might still have hull remains and other finds worthy of excavation preserved beneath the seabed. Another object of the survey was a sonar search in the area near Sciacca that yielded a Bronze Age statuette to a fisherman's net in the 1950's.

Sub Sea Oil Services provided the fully equipped diving vessel *Freebooter* and its crew as part of a training program to provide newly trained divers with open-water experience before they enter the firm's more advanced programs; it is anticipated that the pilot project will lead to a collaboration between AINA and SSOS on the excavation of a shipwreck.

A complete report of the survey will appear in a future issue of the Newsletter.

Current Field Projects

York River, Virginia

On May 5, 1976, AINA began excavation of another ship of the American Revolution. One of a large number of ships and boats sunk during the Battle of Yorktown in 1781, near Yorktown, Virginia, the wreck was first discovered by local sport divers and later, in October, 1975, was carefully examined by archaeologists and historians from the Virginia Historic Landmarks Commission and the Mariners Museum (Newport News). Through the efforts of Ivor Noël Hume, Director of the Department of Archaeology of Colonial Williamsburg Foundation, AINA learned of the urgent need to excavate the wreck.

This year's work is a cooperative effort of the Virginia Historia Landmarks Commissions's Research Center for Archaeology and the American Institute of Nautical Archaeology, with logistical support from the Virginia Institute of Marine Science.

Staff includes George F. Bass, Director; Paul Johnston, Assistant Director; J. Richard Steffy, Ship Reconstructor; veterans of other AINA projects are John Broadwater, Cynthia J. Eiseman, Faith Hentschel, Donald Keith, Cynthia Orr, and Owen Sutton. Field school students participating in the effort are Richard Green, graduate student of anthropology, University of Texas at Austin; Daniel Koski-Karell, graduate student of anthropology, Catholic University of America; Colin Languedoc, undergraduate student of anthropology, University of New Brunswick; Jill Palmer, undergraduate student of anthropology and archaeology, University of Connecticut at Storrs; and Joseph Schwarzer, graduate student of art and art history, SYNY at Binghamton.

New Staff Members

Henry B. Graham

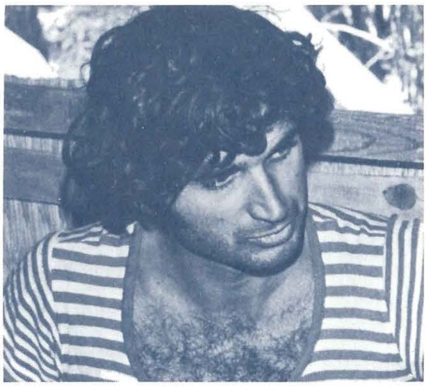
Henry B. Graham, newly appointed Adjunct Professor of Medieval Studies, has taught for the past five years at New College, University of South Florida in Sarasota, where he is Assistant Professor of Art and Archaeology and a coordinator of the Medieval-Renaissance Studies Program. Professor Graham's training was received at Princeton University, the University of California at Berkeley, and New York University. He holds A.B., M.F.A., and Ph.D. degrees from Princeton.

Prior to joining the New College faculty, Professor Graham taught at Washington University in St. Louis and the University of Victoria, British Columbia. While in St. Louis, he organized an exhibit of illuminated manuscripts from the fifth to the eighteenth centuries and was a speaker at the Metropolitan Museum of Art symposium on the year 1200. His publications and research have dealt with ancient Roman glass, medieval stained glass, and medieval manuscript illustrations.

Concerned with bringing his subject matter to life for his students in as many ways as possible, he led a group of 31 New College students to Italy for a term of study in 1972. In 1975 he organized a medieval banquet with authentic foods and entertainment of the middle ages for all students and faculty involved in medieval studies at New College. In February, 1976, he coordinated a Medieval Fair sponsored by New College and the Ringling Museum of Art that was open to the public and drew more than 10,000 people to the event on campus.

While focusing on the medieval period, his teaching and research normally range from antiquity through the Renaissance. Interested in art history as an aspect of cultural history, his courses are often interdisciplinary in approach. His work in nautical history and archaeology goes back many years, and has resulted in course offerings on the archaeology of the sea and on the Mediterranean as a cultural area in antiquity and the middle ages. He is particularly interested in medieval seafaring at the time of the Crusades, when fusion of maritime traditions of Northern Europe and the Mediterranean paved the way for the age of exploration that followed.

In 1975, Professor Graham participated as a field school student in AINA's excavation of the brig *Defence* in Penobscot Bay. He lives in Sarasota with his wife and three children.



Tufan Turanli

Tufan Turanli, a member of AINA's excavation staff at Sheytan Deresi in 1975, has joined AINA as projects manager. Tufan Bey was born in Mersin, Turkey, and received his B.A. in Business Administration from Robert College in Istanbul in 1975. He was recently appointed Director of Istanbul University's Film Center, a post he will continue to hold while involved in management, filming, and public relations for several of AINA's overseas projects. At the same time, he is pursuing a Ph.D. at Istanbul University.

Tufan Bey holds a captain's license, and has been diving for the past four years. His mechanical skills, which kept the "Sheytan Deresi Power Company" going at our 1975 excavation camp, will be as welcomed as his talent for management.

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The American Institute of Nautical Archaeology is a nonprofit scientific/educational organization whose purpose is to gather knowledge of man's past as left in the physical remains of his maritime activities and to disseminate this knowledge through scientific and popular publications, seminars, and lectures. The AINA Newsletter is published periodically by AINA and is distributed to its members and Supporting Institutions to inform them of AINA's current activities.

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