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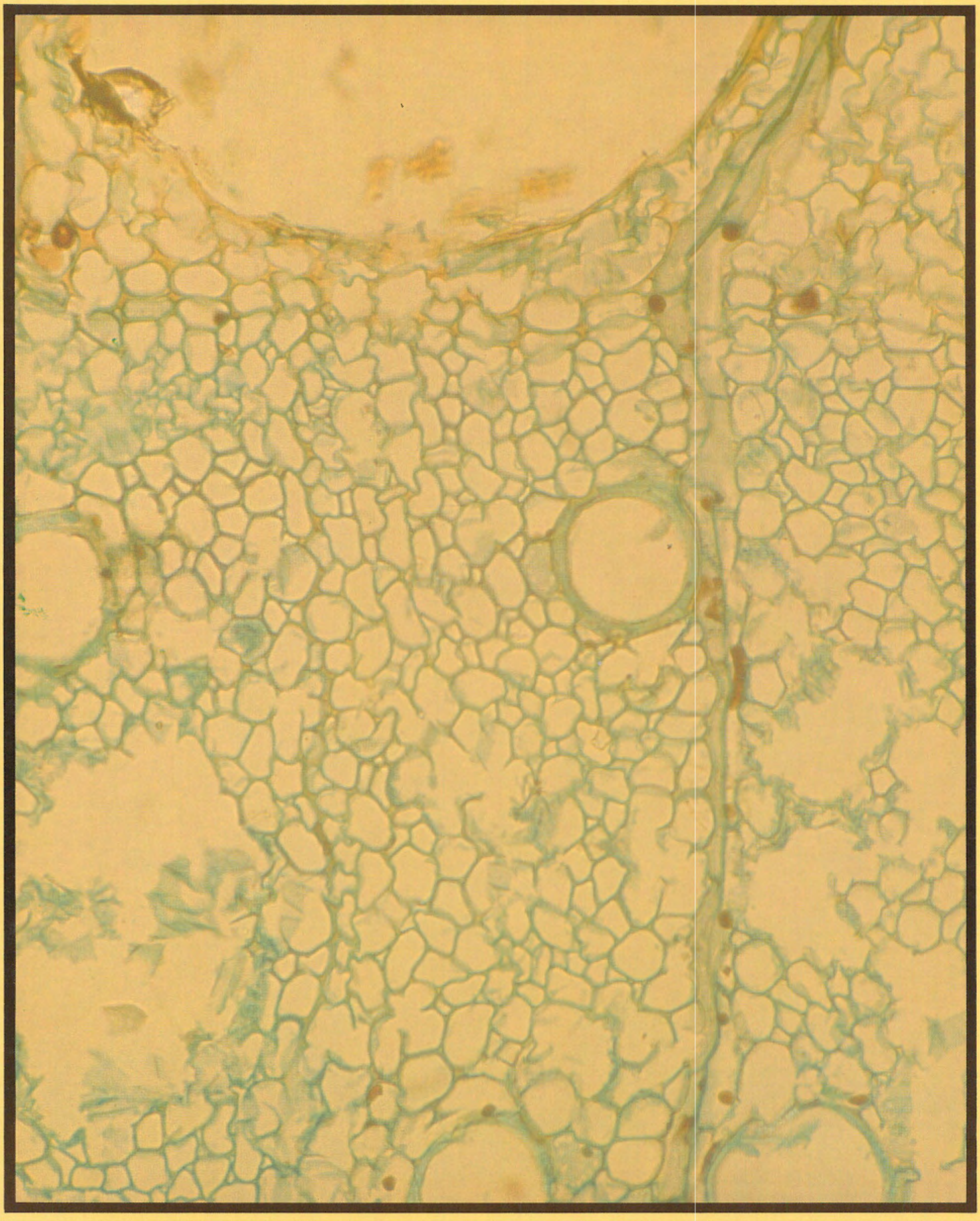

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COVER:
Photomicrograph of deteriorated ash wood, Fraxinus americana, *showing complete loss of cellulose in the cell walls. Only a lignin skeleton is left and, upon drying, some cells have collapsed. The sample, stained with toluidine blue, is from the schooner H.M.S. Tecumseh, built in 1815 and shipwrecked in the Great Lakes. Compare with the section of normal wood on the reverse cover. Approximate magnification: x 300.*

COUVERTURE:
Photomicrographie de noyer cendré Fraxinus americana *détérioré, sur laquelle on remarque l'absence totale de cellulose dans les parois des cellules. Il ne reste que la structure de lignine dont quelques cellules se sont effondrées à cause de l'assèchement du bois. Cet échantillon, teint au bleu de toluène, fait partie de la goëlette H.M.S. Tecumseh, construite en 1815, et qui coula dans les Grands Lacs. Comparez-le avec la coupe transversale d'un bois vert, en contre-couverture. Grossissement: environ 300 fois.*

From the Director-General...

The first issue of the CCI Journal was mainly an overview of the services and activities of the Canadian Conservation Institute. It was necessarily general in scope. This second issue is more specific in that it deals primarily with a single topic — the problems of conserving waterlogged artifacts of wood and other organic materials. The problem is of crucial importance to archaeologists who encounter such artifacts in the water-saturated soils of some prehistoric sites, and also to those engaged in the growing field of underwater (marine) archaeology. The gross form of such artifacts have been preserved because of the conditions of their burial, but once excavated they may not be able to support their own weight and may quickly deteriorate. Ways have to be found to safely remove the water in these objects and replace it with bulking agents. Completely satisfactory methods for doing this have not yet been devised, and the problem is a matter of top priority for research. The need occasioned a symposium on waterlogged wood at the CCI in December of 1976, and it was felt that an issue of our Journal devoted to the topic would also be appropriate and valuable.

Although this issue is somewhat more technical than the first CCI Journal, we hope it is still acceptable to a far wider audience than only professional conservators. We therefore request our readers to write us with comments and suggestions. Future issues can concern intensive coverage of specific areas of conservation and conservation research, or can include more general articles on a variety of subjects. We want the Journal to provide a service to our readers, so we ask that you let us know how we are doing.

K. J. Macleod

K.J. Macleod
Acting Director-General

Two preforms for bowls carved out of a single slab of hemlock. A sample of the water-saturated peat in which the wood was found has been radiocarbon dated to about A.D. 200. From the Lachane Site, Prince Rupert Harbour, on the northern British Columbia coast.

The Problems and Promise of Wet Site Archaeology

George F. MacDonald

The soils over much of Canada are not kind to artifacts of wood, plant fibre, bone and animal skins, of which at least 90 percent of prehistoric native artifacts were made. The soils of the vast boreal and coniferous forests are extremely acid and erode organic materials in less than a century. Over much of the Canadian Shield, there is little or no soil at all to bury discarded tools or weapons, only the exposed bedrock. It is not unknown in Canada for archaeologists to have excavated a site entirely from between the joints and cracks of bedrock outcrops.

Throughout much of eastern Canada, the rate of soil accumulation through time is exceedingly slow. Consequently, preservation is not encouraged by the isolation of cultural deposits from active soil zones. In central Nova Scotia, I excavated a site over ten thousand years old in which the living floors were within inches of the present day ground surface (MacDonald: 1968). Only the most resistant lithic artifacts such as those composed of silicates are preserved in many sites. Even the mineral bands in many varieties of stone may be dissolved by plant acids.

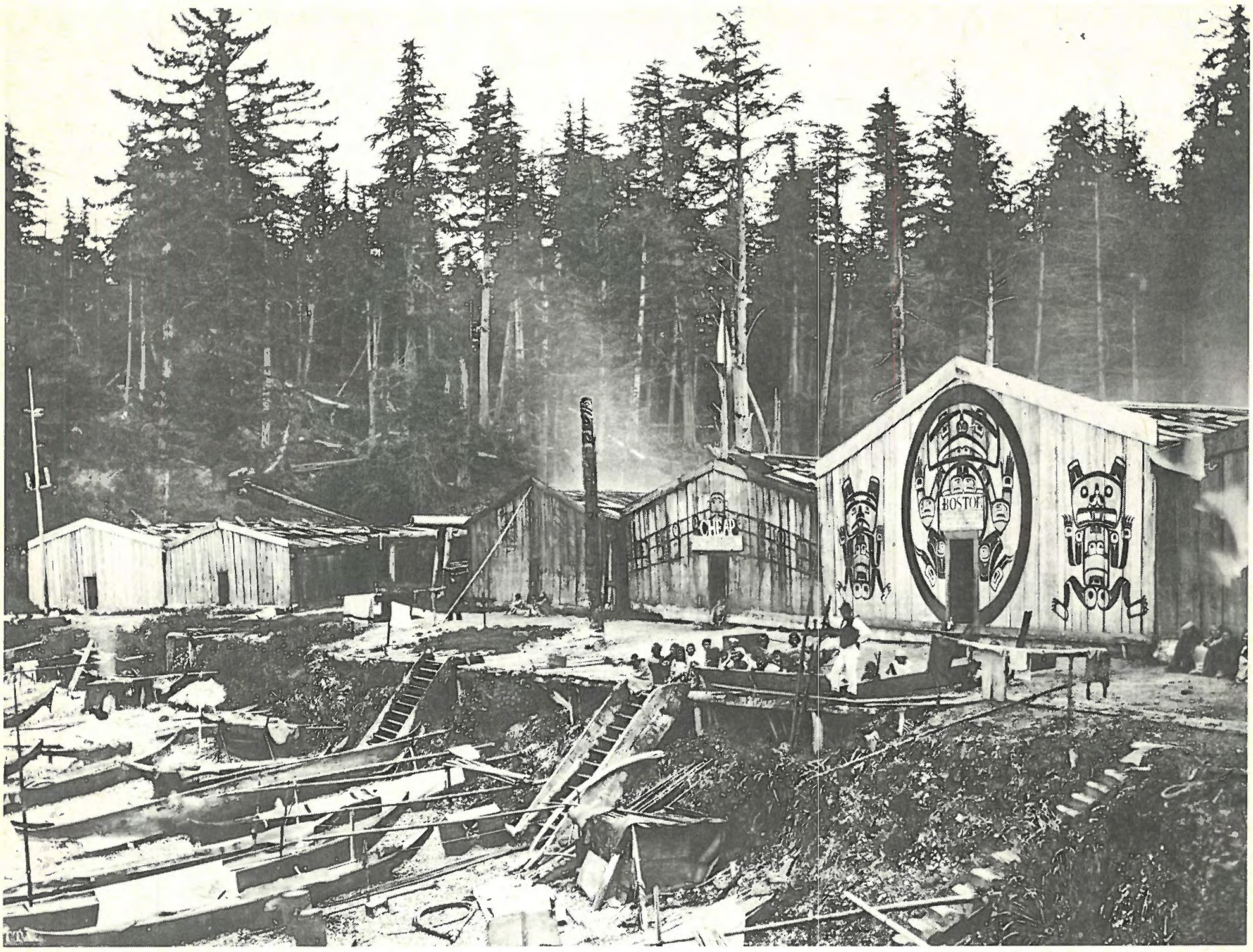
As a result, archaeological assemblages in Canada can reflect only a thin slice of the prehistoric material culture of our native peoples, mainly the tips and edges of their hunting weapons or cutting and scraping tools. Perhaps for this reason, at least in part, the Canadian public does not show the avid interest in our archaeology that museum-goers in other countries do in theirs. This is reflected in the fact that there are few specialized archaeological exhibits in museums or at sites developed for the public to visit across the country. Nor, for that matter, is there much concern over preserving our thirty thousand-year record of human occupation in Canada from the common dilemma of archaeology today — the rapid destruction of archaeological sites by bulldozers and other agents accompanying modern urban and industrial development. Thousands of prehistoric sites, big and small, are being destroyed annually without any archaeological work whatsoever being done on them.

Left in sufficient soil matrix for support, an extremely fragile birchbark tray is carefully slid onto a metal sheet. Lachane Site, northern British Columbia.

Public apathy to Canadian archaeology cannot be due to a lack of interesting developments in our prehistory, nor to a lack of beautifully crafted native material culture. Ethnographically, the material culture of Canada's native peoples is among the finest in the world, and was much sought after in the last century by foreign museums. The monumental sculpture of the West Coast tribes, the elaborate basketry of the southern interior of British Columbia, the highly styled clothing of the Plains tribes and the Naskapi, and the delicate carvings and engravings of the Inuit are but a few examples. However, since the vast majority of native architecture, clothing and ceremonial paraphernalia was of hides, bark, wood and plant fibres, it is usually assumed that most of these objects have long since perished.

Yet, from time to time, a chance find is made whereby we catch an intriguing glimpse of prehistoric artifacts made from highly perishable organic materials, those which have been preserved in an archaeological deposit by some unique feature of the soil environment. We have now come to realize that almost total preservation of ordinarily perishable cultural remains can be found in site deposits permanently saturated by water. Such deposits are called "wet sites" by archaeologists, and represent one of the most exciting challenges to archaeology today.

The phenomenon of occasional perishable items turning up remarkably well preserved in wet soils did not escape our predecessors in research. In 1927, when W.J. Wintemberg excavated the Roebuck Site, a 13th-century Iroquois village in eastern Ontario, he discovered worked pieces of wood and bark in areas where the middens at the edge of the settlement disappeared into a swamp that almost surrounded the village. At that time, Wintemberg did not



The village of Xumtaspi on Hope Island, British Columbia, in an 1884 scene, offers a glimpse of the elaborate culture of Northwest Coast peoples in aboriginal times. Wood was a plentiful and extensively used raw material in this region. It can survive for thousands of years buried in the middens on which such settlements were built, if the deposits remain waterlogged.

have the specialized equipment necessary to pursue his finds. In the 1940s, dredging operations off the Skagit River delta near the border of British Columbia and the State of Washington brought up a carved wooden atlatl (spear thrower) that had lain on the bottom of the Strait of Georgia for a millenium or more. A note on this find was published by Carl Borden (1969). In eastern Canada, dugout canoes have frequently been washed from eroded riverbanks, and some of them appear to be thousands of years old. At least a half dozen such examples have been documented by Kenneth Kidd (1960). Most ended up as curios in local museums or, less nobly, served as pig troughs on farms until they finally disintegrated and were lost.

Wet site archaeology in Europe has been pursued with a passion since the 1850s when the first Swiss lake dwellings appeared above the surface of Lake Neuchâtel during periods of low water levels. Wealthy amateur archaeologists, such as Colonel Frederick Schwab, dredged many sites of this kind, including the classic Celtic causeway site at La Tène where thousands of iron weapons with wooden handles intact were recovered. Work still goes on at lake village sites at Neuchâtel and other lakes in Switzerland. Similar sites, with remarkably well preserved structures and items of wood and basketry, also have been discovered in shallow lakes in Italy and Yugoslavia.

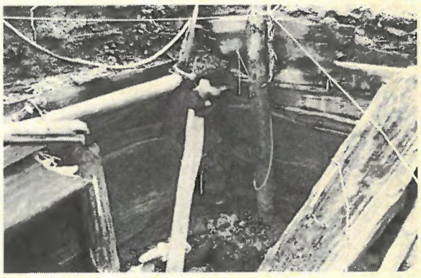
One of the most remarkable excavations took place at an early Mesolithic site at Star Carr in Yorkshire, England. Grahame Clark (1954) pioneered many new techniques of excavation and preservation there, and produced an exemplary report on the antler and wooden tools from this 10,000-year old site. The result was an entirely new perspective on the importance of fishing in Mesolithic cultures that has since been confirmed by work at wet sites elsewhere in Europe.

In the Somerset lowlands of England, Neolithic timber-lined trackways have been traced for many miles across marshes. Although their function is not yet entirely clear, many axes, mallets and other tools used in their construction have been discovered and dated. Perhaps the oldest perishable remains have come from Torralba, Spain, including wooden spears which date back almost 300,000 years.

More recently, the potential of wet site archaeology has been recognized in other regions of the world and is contributing valuable insights to the fuller understanding of prehistoric cultures in those areas. A team led by Jack Goulson of the Australian National University has recovered wooden agricultural tools thousands of years old from irrigation ditches in the New Guinea highlands. In New Zealand, a few years ago, a trove of over 300 carved wooden combs were found; they had been purposefully deposited in a swamp, presumably as a precaution against supernatural powers the Maori believed were associated with combs once their owners were deceased. Since then, carved house rafters and elaborate canoe stern boards and prows have been found preserved in the swamp muds where they were hidden from prehistoric raiding parties. Archaeologists have just begun to excavate sites of large Maori villages, which were built on knolls within swamp areas for defensive purposes. Such sites are numerous in New Zealand and promise to yield much valuable information on the early development of the distinctive Maori art style.

In the United States, at least three sites are worthy of special mention. The earliest to be investigated was the Key Marco Site area in Florida, which produced dozens of painted masks and carvings, along with hundreds of other wooden and organic artifacts recovered from silted canal deposits (Gilliland: 1975). Most of these finds were made in the 1920s when proper conservation techniques were not available. Consequently, many of these unique items have badly deteriorated.

An equally important site is that at Ozette on the Olympic Peninsula of Washington State. Over 50,000 perishable artifacts, including most of the house timbers and the contents of several communal plank houses, have been recovered. The houses had been covered by mudslides from adjacent slopes, which sealed the deposits and kept them water-saturated. An extensive inventory of late prehistoric material culture, including many carvings, elaborate whaling equipment, blanket looms and hundreds of baskets, makes possible a detailed assessment of southern Northwest Coast Indian culture and technology prior to White contact. Modern conservation techniques have been used, and a magnificent museum facility to house this collection is being constructed on the Makah Indian Reservation at Neah Bay, Washington (Gleeson and Grosso: 1976).



Extensive waterlogged remains of a village at Ozette, some 20 km south of Cape Flattery on the Washington coast [below]. Behind the portions of whale skeletons in the left foreground is a partially standing house wall of overlapping planks at right angles to the beach. The above photograph shows detail of a house wall corner. A freshly exposed panel of a plank house [top] bears carvings which probably represent wolf and thunderbird motifs. The thousands of perishable artifacts recovered here, dating mainly to the period just prior to White contact, have revealed many gaps in the material culture of the Northwest Coast as represented in existing museum collections.

Locations of the excavated Pacific Coast wet sites discussed in the text. Archaeologists predict that such sites will be found in great abundance in this part of the world.

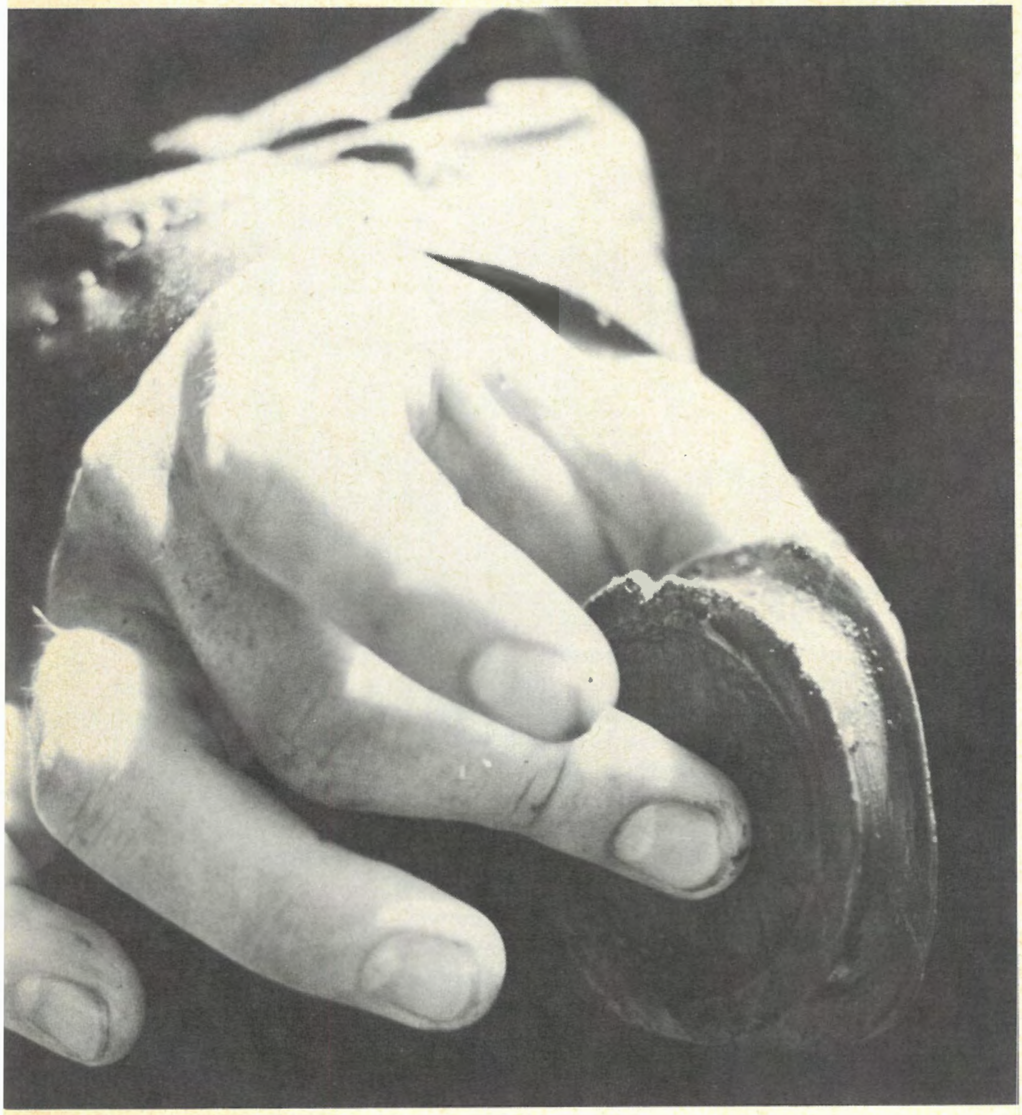
Another select example from the United States is a site on a small island in the Mississippi River in Louisiana, a site where salt deposits have attracted animals and human hunters for more than ten thousand years. Extensive wet deposits have been traced in cores over forty feet deep in the river alluvium. One of the major problems that has held back full-scale archaeology on the island is the expense involved in removing the deep overburden. Tests show that some of the basketry recovered at this site may date back to Clovis occupations some 10,000 to 12,000 years ago.

Recent developments in Canadian wet site archaeology have been primarily on the coast of British Columbia. This appears to be due to several factors. The vast accumulations of cultural debris at winter village sites, combined with the high precipitation rates on this coast, frequently cause stream blockage and result in permanently wet deposits. Some sites occur in intertidal zones beneath layers of river silts or on drowned sections of coastline. Perhaps another factor stems from the frustration experienced by West Coast archaeologists who deal with a rich but highly perishable material culture that does not survive long in dry deposits. Thus archaeologists, particularly those interested in tracing the development of arts styles on the coast, have deliberately searched for and excavated wet sites.

To date, four important wet sites have been excavated in British Columbia. On the Musqueam Indian Reserve in Vancouver, Charles Borden (1976) excavated a water-saturated layer at the base of a shell midden and discovered many fine examples of woven fish nets and baskets as well as wooden tools which date back to about 1,000 B.C. On Vancouver Island, near Qualicum Beach, a change in the course of the Little Qualicum River began the erosion of an ancient but as yet undated deposit that contained more basketry and cordage (Simonsen: 1976). Efforts were directed at protecting this site from further erosion rather than towards extensive excavation, but these efforts were not successful and emergency rescue excavations have had to be undertaken. On the central coast, in Bella Coola territory, a crew from Simon Fraser University has investigated prehistoric wet deposits in an intertidal estuary of the Kwatna River. The river is eroding a new course. Approximately 400 artifacts of perishable materials, including wooden wedges, fish hooks, points and shafts were recovered, along with cordage and woven materials that included baskets and even a hat. Most of the material from the Kwatna midden, probably domestic refuse from nearby homes and not the remains of specialized activities, dates to within the last few hundred years just prior to the beginning of the 19th century A.D. (Hobler: 1976).

In 1968, on the northern British Columbia coast at Prince Rupert, a small area of one of the large shell middens at the Boardwalk Site was found to be water saturated. Limited excavations there in 1969 and 1970 yielded a small number of preserved wooden and bark artifacts, including a small carved seal, a digging stick and a wooden wedge. In 1970, testing at a nearby site on Kaen Island indicated a much larger wet deposit in a stream bed between two large

Gently spraying with hoses to wash away the soil, archaeologists are able to find many fragile artifacts which would be lost if other conventional excavation techniques were used. An Archaeological Survey of Canada team at the Lachane Site, northern British Columbia.



A mark of beauty and status, a labret of wood, stone or bone was worn by inserting it in a hole cut in one's lower lip. Two of wood have been recovered from the Lachane wet deposits. A Haida woman [below] from the Queen Charlotte Islands was wearing one when she was photographed in 1884. The practice died out by the end of the century.

lobes of the midden. In 1973, this site, Lachane, became a major rescue project when the Ministry of Transport decided to build a deep-water shipping terminal on top of the site. A crew of 20 from the National Museum of Man in Ottawa worked for five months at the shell midden and wet deposits, recovering over 400 perishable artifacts. Hydraulic pumps and hoses with adjustable nozzles were used to wash away the mucks and gravels from the deposit. Surprisingly, little damage was done to the perishable materials during excavation, with the exception of shredded cedar bark that had to be protected from the direct spray of the hose. Large birchbark trays posed another problem in that the bark was inclined to dry rapidly and to warp and crack extensively once it was freed of its protective mud coating.

The deposit at Lachane reached a maximum depth of five feet in the middle of the stream bed. Because of disturbance in the first foot or so below the surface, caused mainly by the installation of military facilities on the site during the Second World War, only a few preserved wooden artifacts were found in this uppermost zone, and every one was deteriorated almost beyond recognition. However, the lower layers contained vegetable fibres and branches amid stones and gravel, in addition to the many well preserved artifacts. At the bottom were beach gravels and the trunks of large trees bearing unmistakable traces of adze marks from the time the site had been originally cleared. One adzed stump was found to be 2,470±90 years old (about 520 B.C.),while other dates ranged to as late as 1,630±100 years ago or A.D.320. These dates correspond roughly to the middle horizon of the Prince Rupert archaeological sequence which begins just over 5,000 years ago.

Woodworking was well represented in the Lachane assemblage. Seventy-five wooden wedges, three chisel handles and an elbow adze handle were found. Many unfinished wooden items document stages and methods of manufacture virtually identical to those recorded in early historic times. Bentwood boxes and wooden bowls, for example, were adzed with clean broad cuts that were previously thought to have been imposible to produce without metal cutting tools. Other men's utensils included harpoon and arrow shafts and five canoe paddles. Thirty-six clam and root digging sticks, many with fire-hardened tips, represented the most important of the women's tools on the site. Containers included four wooden bowls, eight bentwood box fragments, three birchbark trays and 17 baskets.

Basketry proved to be the most diagnostic material from the entire Prince Rupert assemblage. Almost all of the baskets were constructed on square checkerwork bases of red cedarbark strips. In examining ethnographic collections in various museums, it was noted that this type of base, in combination with other basketry construction featured at the Lachane Site, clearly distinguishes the basketry of Tsimshian-speaking peoples from that of their Tlingit and Haida neighbours who utilize circular bases of spruce root for most of their basketry. Because baskets involve complex construction techniques yielding a large range of attributes for study, and since they occur in considerable numbers in most West Coast wet sites, they provide an ideal substitute for ceramics (which do not occur in this region) for measuring the degrees of relationship between assemblages from various sites.

The only items of personal adornment found at Lachane were two wooden labrets (carved plugs worn by inserting them in a slit cut in one's lower lip). Although in historic times labrets were used only by women, stone labrets have been found with burials of both sexes in the Prince Rupert area. The only elaborately decorated item from the site was a red cedar handle, carved in the form of an animal's body, from the lid of a bowl or box. (A photograph of this artifact appeared on the cover of Volume 1 of the *CCI Journal.*) It is noteworthy that this carving, although stylistically related to West Coast sculptural traditions in general, is nevertheless quite different from the zoomorphic forms of wood carving from historic times.

Almost all of the items from the Lachane Site were either broken or unfinished, and had been discarded in a little-used wet area between two house platforms that served occasionally as a dump. Further details on this assemblage are available in Inglis (1976).

In conclusion, several points about wet site archaeology in Canada need to be stressed. From my experience, wet sites spanning at least the last few thousand years occur all across this country. Their rarity in the archaeological literature is mainly due to the fact that archaeologists tend to ignore their existence. Wet deposits occur generally on the periphery of village or camp sites near the source of fresh water used by the inhabitants. The fall-out of detritus from the various manufacturing, food collecting, and other activities of villagers tended to cover hundreds of feet beyond where the archaeologist usually defines the limit of the site, especially at sites that were occupied for a considerable period, a few decades or more, even if only seasonally. This fall-out zone, if searched carefully, often incorporates areas of permanently wet

Spraying water through a screen, archaeologists wash away beach muck from basketry and spruce root cordage recovered at the Little Qualicum River Site on Vancouver Island's east coast [above]. The badly eroded beach terrace of this tidal estuary also yielded, besides faunal remains [left], numerous wooden wedges, stakes and other prehistoric artifacts one might expect to find at a seasonal fishing-hunting encampment. These objects, some of which would disintegrate readily if handled carelessly, were consolidated by bathing them for two to six months in a 50 percent solution of polyethelene glycol. At present, this is the most practical and effective way for archaeologists to stabilize waterlogged artifacts.

soil conditions. These may occur at or near springs, beds of streams, pockets of marshy land or even buried seepage layers beneath the surface. Such areas can be easily detected with simple coring devices, but for some reason this is rarely done as a routine in site excavations, or at least has not been done for the purpose of finding wet soil zones in the activity areas around occupation sites.

Part of the problem stems from the traditional excavation techniques of archaeologists — they are oriented to dry ground. Trowels and whisk brooms simply do not work in soggy, water-saturated excavations. A certain amount of mechanical equipment is required to pump water into or out of the excavation, but this can usually be rented at moderate cost for a season. Fortunately, the experiences of a number of archaeologists, particularly those working on the West Coast of North America, are being published promptly, and novice wet site archaeologists can benefit from the trials and errors of others.

The conservation problems involved in wet site archaeology certainly have not been covered here, and they should not be underestimated. However, besides the rapidly growing literature in this field, we are fortunate in Canada to have considerable expertise, available for consultation to any archaeologist, from the Canadian Conservation Institute in Ottawa and the Conservation Training Programme at Queen's University in Kingston, Ontario. My own museum experience suggests to me that we can add very significantly to the spectrum of prehistoric technology and art by venturing more into the realm of wet site archaeology, and that, in fact, the appreciation of our prehistoric and historic heritage by the general public depends greatly on how we face the current challenge of wet site research.

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Waterlogged Artifacts: The Nature of the Materials

Mary-Lou Florian

Waterlogged "archaeological" material merely implies recovered artifacts and other debris that have been saturated with water for a long period of time. The fact that a piece of wood, for example, has archaeological significance does not make it different from any other organic material in the natural process of decay and recycling. It is subject to the same physical and chemical deterioration and attack by microorganisms as any piece of buried wood. It will eventually end up as recycled carbon, coal, or fossilized wood, depending on the type of environment in which it is buried.

Thus, the state of deterioration of waterlogged wood from archaeological sites varies widely. This, with the extreme distortion which can occur when the wood dries out, makes the task of conservation difficult. In order to discuss the deterioration of waterlogged wood and the problems involved in its conservation, however, one must first become familiar with the nature of the material itself.

The fact that green, fresh-cut wood splits when it is first dried is common knowledge. These splits always occur on the radius; that is, from the outside into the centre of the tree trunk. The reason for this lies in the cellular structure of wood. Wood is the water-transporting tissue of a tree. It is made up of a variety of cells of different shapes and cell wall thicknesses. About 90 percent of the cells in softwoods, such as pine, are wood tracheids, and 80 percent of the cells in hardwoods, such as ash or oak, are vessels and wood fibres. These cells are the main water-transport cells, and also give the wood its mechanical strength. The other cells are involved in food transport and storage. All the cells are glued together by a pectin substance in the middle lamella area between the cells.

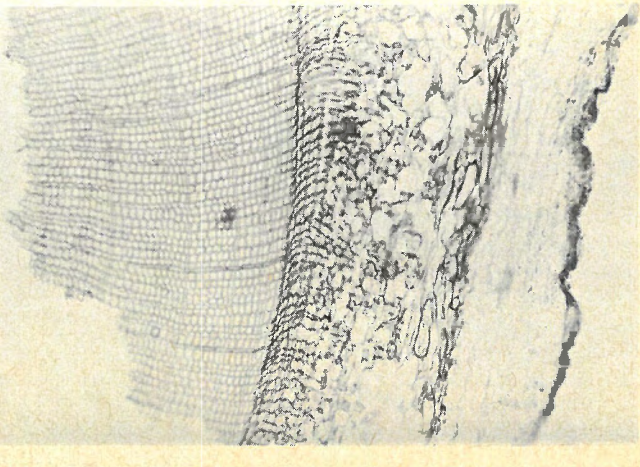
Wood can be compared to a handful of drinking straws glued together. In this analogy, the straws are not randomly oriented but are in radial rows and in circular growth rings. Their ends are tapered and interwoven. Water can flow throughout the tissue because all the cells are interconnected with valved openings called bordered pits. When green wood dries, the tangential walls (oriented around the circumference of the tree trunk) of the cells shrink more than the radial walls. This causes a pull around the tree trunk which is released when the wood splits. If green wood is dried slowly or under controlled conditions, as is done in the lumber industry, this splitting can be prevented.

Upon drying, waterlogged wood may have radial cracks as well as cracks in other directions. The reason it behaves so differently from green wood is because it has undergone, besides waterlogging, some type of deterioration. In deteriorating, regardless of what agent caused it or the length of time involved, some loss of structural strength of the cells and tissue has occurred. When such wood dries, water evaporating from inside the cells causes a pull, like sucking on a straw, and the weak cell walls may collapse. The glue-like middle lamella which holds all the cells together may be gone and when the tissue dries, it disintegrates into separate cells. The normal shrinkage rates of cells are changed and, on drying, the wood may split, warp, and contort in every which way. The surface make flake off or form a checkerboard crack pattern. No two pieces react in the same way.

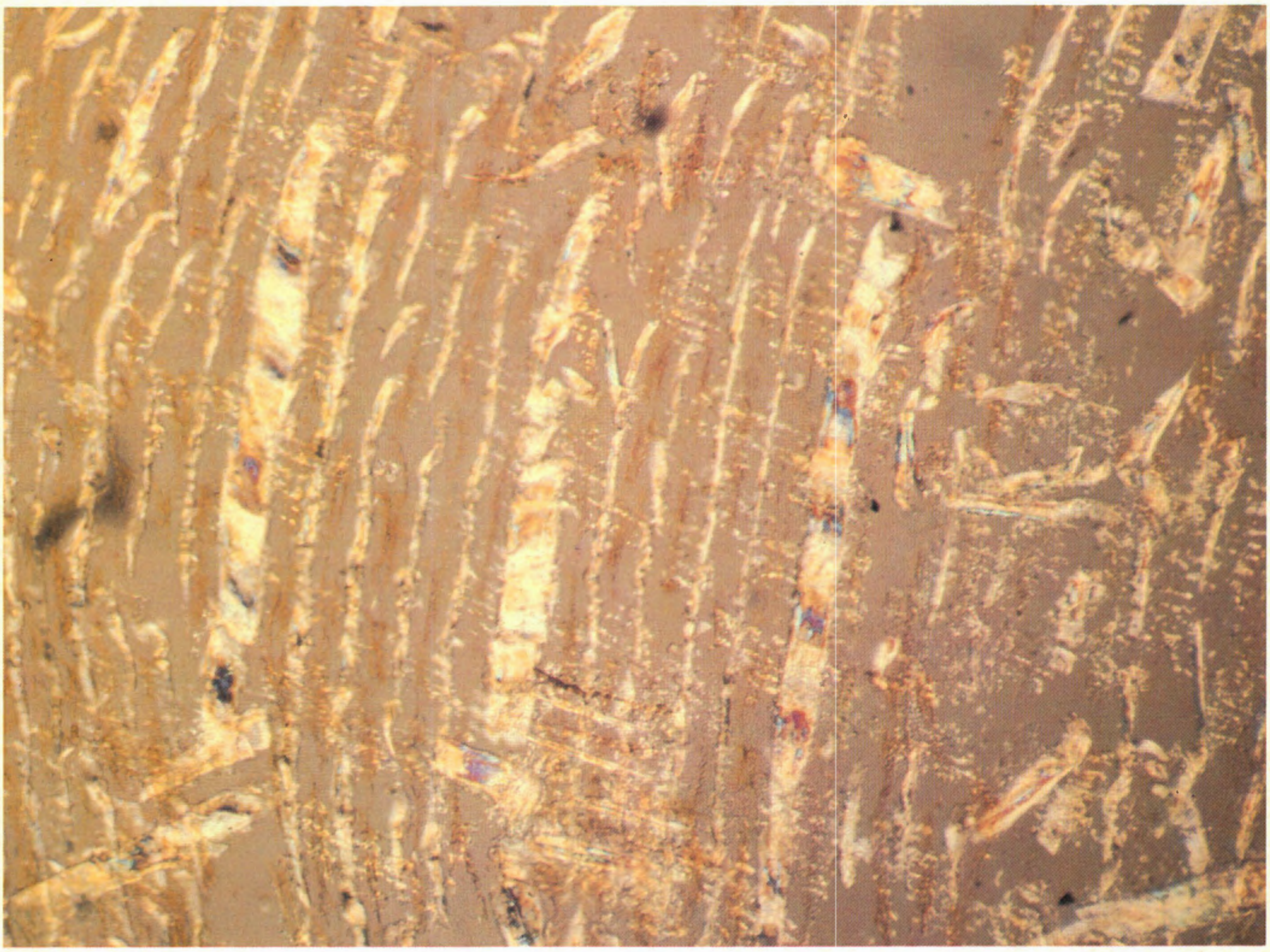
The nature of the deterioration results from a number of factors and, as stated above, it may be at any stage, from almost fresh wood to recycled carbon. The wood, upon excavation, may look quite normal, or it may be mushy, spongy or like burnt toast. This variability may be caused by the soil chemistry of the site. In acid bogs, wood remains for long periods, whereas in an alkaline shell midden, it is quickly dissolved away. Moreover, some wood species are more resistant to deterioration than others. For example, the heartwood of white oak is very resistant to decay because of its hardness, sealed bordered pits, and plugged vessels.

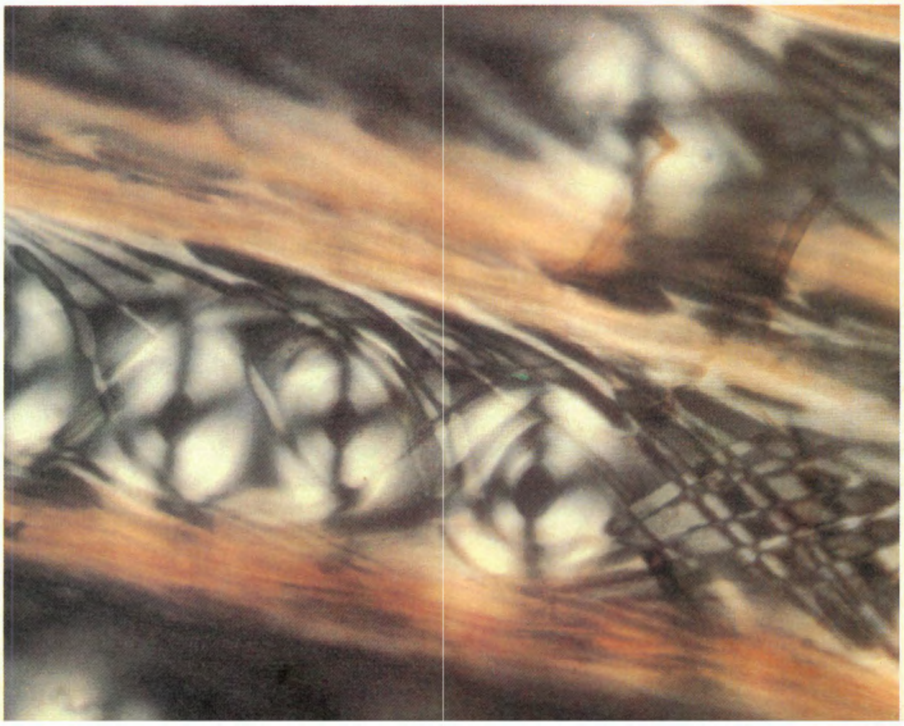
Besides the chemistry of these deteriorating environments, microorganisms are also major agents which

Section from a small branch of western red cedar, Thuja plicata. *On the left is the wood, regular rows of tracheids in growth rings. Next is the secondary phloem, the tissue used by West Coast Indians for making basketry. The clear region on the right is the true outside bark, made up of corky cells which are sloughed off as the tree grows.*

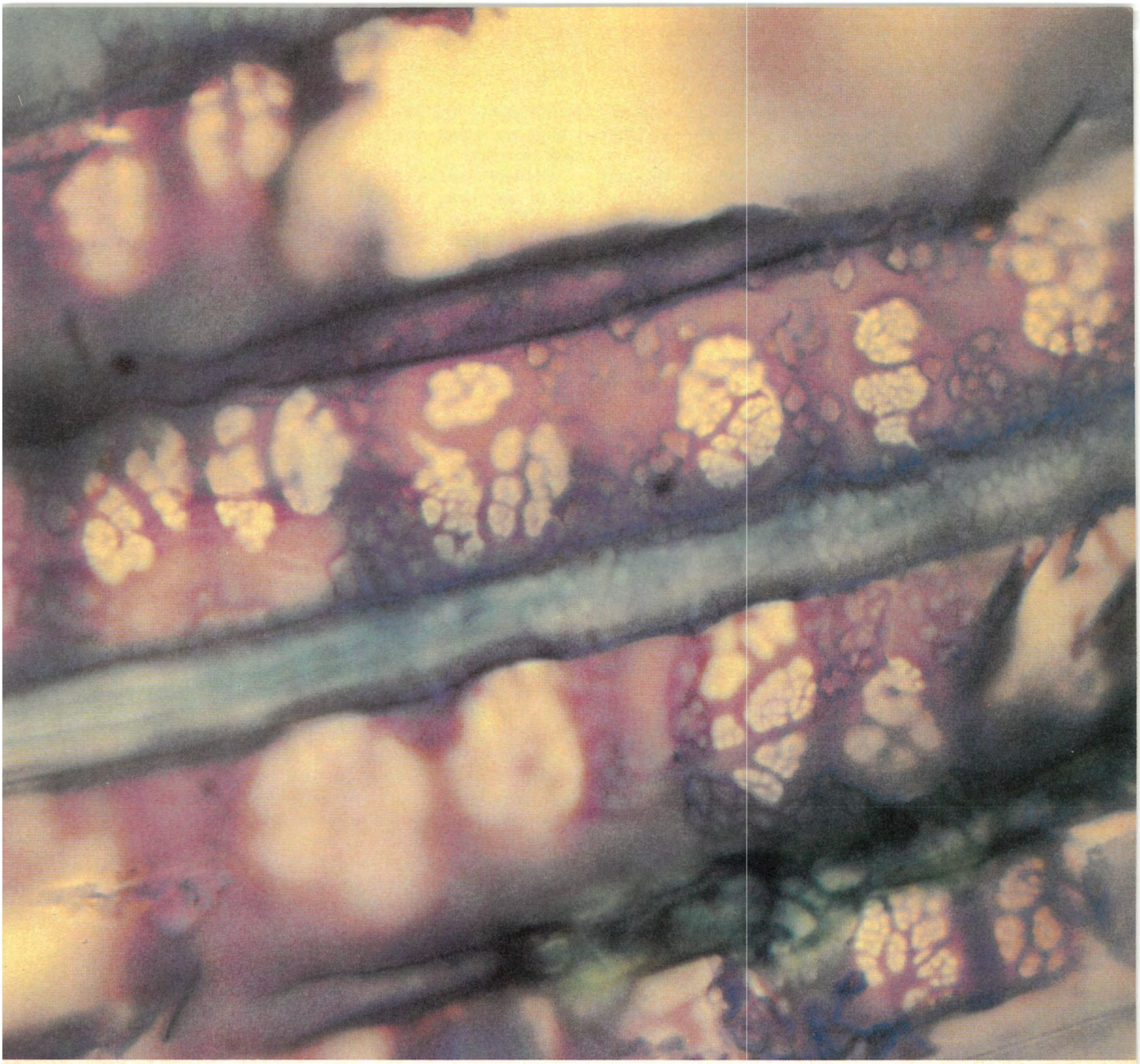


Photomicrograph of normal phloem (bark) of western red cedar, Thuja plicata, *unstained and viewed with polarized light. Vertical light bands, small and large (average width .05 mm), are the phloem fibre cells. Three or four large fibres comprise one year's growth. Patches of inorganic crystals, which appear as horizontal angled lines, are calcium oxalate, a waste product of metabolism.*





Deterioration caused by soft rot fungi can be seen in a sample of eastern white pine, Pinus strobus, *taken from a waterlogged dugout canoe. The bordered pits (.02 mm in diameter) in the tracheids show a characteristic cross pattern when viewed under polarized light. Crystalline cellulose in cell walls and bordered pits shines; dark lines twisting around the pits are bore holes made by the fungi, which have digested the cellulose in these areas. The canoe was found in about 2.5 metres of water in a lake at Maniwaki, Quebec.*



Normal phloem (bark) of western red cedar, Thuja plicata. *The tissue is stained with toluidine blue, which colours the fibres blue and the sieve cells purple. The circular porous sieve plates allow transport of food through the tissue.*

attack the structure of the buried wood. Bacteria are everywhere in soil and water. Many can use the main chemical of wood, cellulose, as food. They break it down by extracellular enzyme digestion and absorb the end product, soluble glucose. Other bacteria can only digest the pectin material, which is the main chemical in the membranous valves of the bordered pits. These bacteria are usually the first to enter the wood. They destroy the valves of the bordered pits and make the wood more permeable to water. This starts a whole succession of organisms. The cellulose-digesting bacteria may then enter, as well as some fungi.

When wood is initially buried or submerged, there is enough air around it to support some surface fungi growth. Like the bacteria, there are many groups of fungi which can use only certain parts of the wood for food. The moulds or sap stain fungi utilize only the stored food; these do not destroy the strength of the wood. When wood is saturated with water, soft rot fungi may grow and form a thin surface of destroyed cells. It is this surface which, on drying, forms a pattern of checkerboard cracks. The hyphae of the soft rot fungi tunnel into the inner layer of the cell wall. They follow the spiral orientation of the cellulose microfibrils in these walls. Soft rot is the major cause of deterioration of wood at ground level, such as fence posts or wood used in structures that are continuously in contact with water, such as water-cooling towers.

When there is not enough oxygen left to support fungi growth, another group of bacteria may move in as scavengers and clean up what is left. Few microorganisms can digest lignin, the other major chemical in the cell walls, so what is often left is a cellular skeleton of the lignin. (Another group of fungi, the decay fungi, can use the lignin, as well as the cellulose, in the cell walls. However, these are not active in water-saturated wood. If excavated wood shows evidence of deterioration by these fungi, it must have occurred before it became saturated in water.)

Some materials, due to their structural nature, have a built-in mechanism for deterioration. Such is the case with the bark of western red cedar, *Thuja plicata*. Waterlogged deposits at the Lachane Site on the northern British Columbia coast have yielded many fragments of cultural items of this material, such as basketry, woven hats and cordage. Excavated by the Archaeological Survey of Canada, these objects are presently at the CCI for conservation treatment.

Actually, the "bark" is misnamed. In this case, we are not referring to the same tissue as birchbark, which is true bark on the outside of the tree, but rather the underlying food-transporting tissue called the phloem. (Remember, the wood is the water-transporting mechanical tissue.) The phloem, like the wood, grows each year and forms growth rings outside the wood. On branches or on young cedar saplings the tree bark is present and protects the phloem, but on the trunks of the giant mature trees it has long gone.

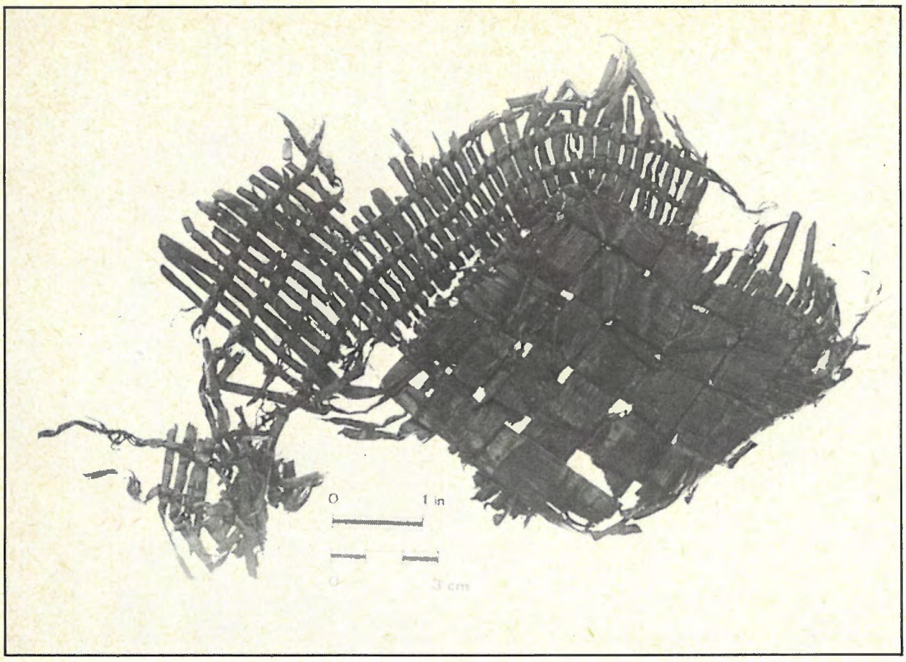
The phloem itself has two distinct regions: the inner white region which is the living tissue, and the outer, dark brown, dead phloem which is no longer able to transport food and acts to protect the inner living tissue from injury and weathering. As the tree grows in girth, the phloem allows for the increase in diameter by splitting lengthwise as well as into thin sheets. It is this feature which makes the cedar phloem a favorite material for weaving. Only the dark brown, dead phloem was used; it requires little preparation because it is easily stripped from the tree and split into thin, strong, flexible strips which are water-resistant and decay-resistant and are easy to weave.

All these features result from the structure and chemistry of the tissue and its cells. Cedar phloem tissue is basically made up of three types of cells: extremely strong hair-like "fibres"; delicate cubical food-storing cells (the "parenchyma"); and porous food-conducting cells (the "sieve cells"). The fibres are about three millimetres long and a hundred times thinner. However, they have such thick walls that there is only a small opening in the middle. In cross-section, they are rectangular or square. Sieve cells are about the same dimensions as the fibres, but have thinner walls. Along the radial walls of sieve cells are sieve plates through which food and cytoplasm moved when the tissue was living. Small pits on both fibre and sieve cell walls allowed free movement of fluids between the cells. The parenchyma cells are organized longitudinally and radially in phloem. Starch is stored in the longitudinal cells and inorganic crystals in the radial cells.

Even though all these cells are cemented together with pectin, the three cell types are organized in such a way that the phloem easily separates in sheets. The separation occurs by the breaking of delicate parenchyma cell walls adjacent to strong fibers. This happens at three levels, giving sheets of three different thicknesses. First, each season's growth is separated by a few rows of true bark cells, which are water-resistant cork cells and starch-storing circular parenchyma. Each growth ring easily separates at this weak junction. Second, within any one growth ring, rows of large square fibres alternate between four rows of thin rectangular fibres. Separation easily occurs between the fibres of such different strengths. Finally, between the thin rectangular fibres are two sieve cells separated by a row of thin-walled, starch-storing parenchyma cells which are easily broken. In addition, the radial parenchyma cells are full of inorganic crystals which can act as an abrasive to destroy the cell walls and thereby cause longitudinal splitting. It is no wonder that a piece of cedar phloem rubbed between one's hands breaks readily into individual fibres.

Knowledge of normal tissue is essential before analyses of the archaeological material can be undertaken. Microscopic examination of the archaeological basketry material shows intact fibre cells. The holes in the sieve plates and pits have enlarged. The starch bodies and inorganic crystals have gone, although some unidentified resinous-looking material is still in the sieve elements. All the thin-walled parenchyma cells have virtually disappeared. Occasional bore holes of soft rot fungi appear on the sieve cell walls. The pectin adhering all the cells together is gone, and the cellulose of the cell walls has either gone or been chemically changed. The cell walls have a crystalline look which may be due to inorganic salt impregnation, the first step in fossilization. Chemical analysis shows the material to have abnormally high amounts of iron. Furthermore, most of the insoluble resins and tannins of the bark are still present, but in greatly reduced amounts. Even the phlobaphenes which in part give the material its rich brown colour are still present. However, degraded cedar phloem has darkened considerably, and the natural colours are masked.

Vegetal material in a water-saturated environment should ordinarily deteriorate. Yet, why has such a delicate tissue as cedar phloem, despite its natural tendency to disintegrate readily, remained for over 2,000 years in the Lachane deposits? Part of the reason this



Clockwise from above: basketry fragment from the Lachane wet site; Nootka woman with woven bark cape and basket digging for roots in 1915; Tsimshian woman, Mrs. Dorothy Brown of Kitkatla, British Columbia, making a cedarbark basket in 1972. The basic techniques of weaving cedarbark have not changed since prehistoric times.

tissue has resisted degradation is the high lignin and tannin content in the cell walls of the fibres and sieve walls. As noted previously, very few microorganisms can digest lignin, and even if they were present, the tannin is toxic to them.

The waterlogged deteriorated tissue of such recovered basketry does not have any inherent strength, compactness or unity, and the only thing that actually kept it together for so long was the compacted soil matrix in which it was buried. Now that it is removed from this natural packaging element, the felting of the fibres and other cell remains is all that keeps it together. It is this puff of fibres and cell remnants that has to be conserved.

As for wood, the problems of conservation stem mainly from the highly variable degrees of deterioration it has undergone. There are methods of consolidating and impregnating such wood which prevents extreme dimensional changes. But these techniques are often cumbersome, costly and produce aesthetically unacceptable results. Major research in conservation processes for water-saturated archaeological wood is going on all over the world. But, there is yet a great need for detailed studies of the state of the material to be conserved. Furthermore, there is a dearth of comparable information on the condition of the wood with relation to the burial environment. Now archaeologists are being requested by conservators to record information about the burial sites of individual artifacts. Archaeologists as well as conservators will benefit from this information. With these data, along with studies of the deteriorated wood and other organic materials, meaningful research on conservation treatments can be accomplished.

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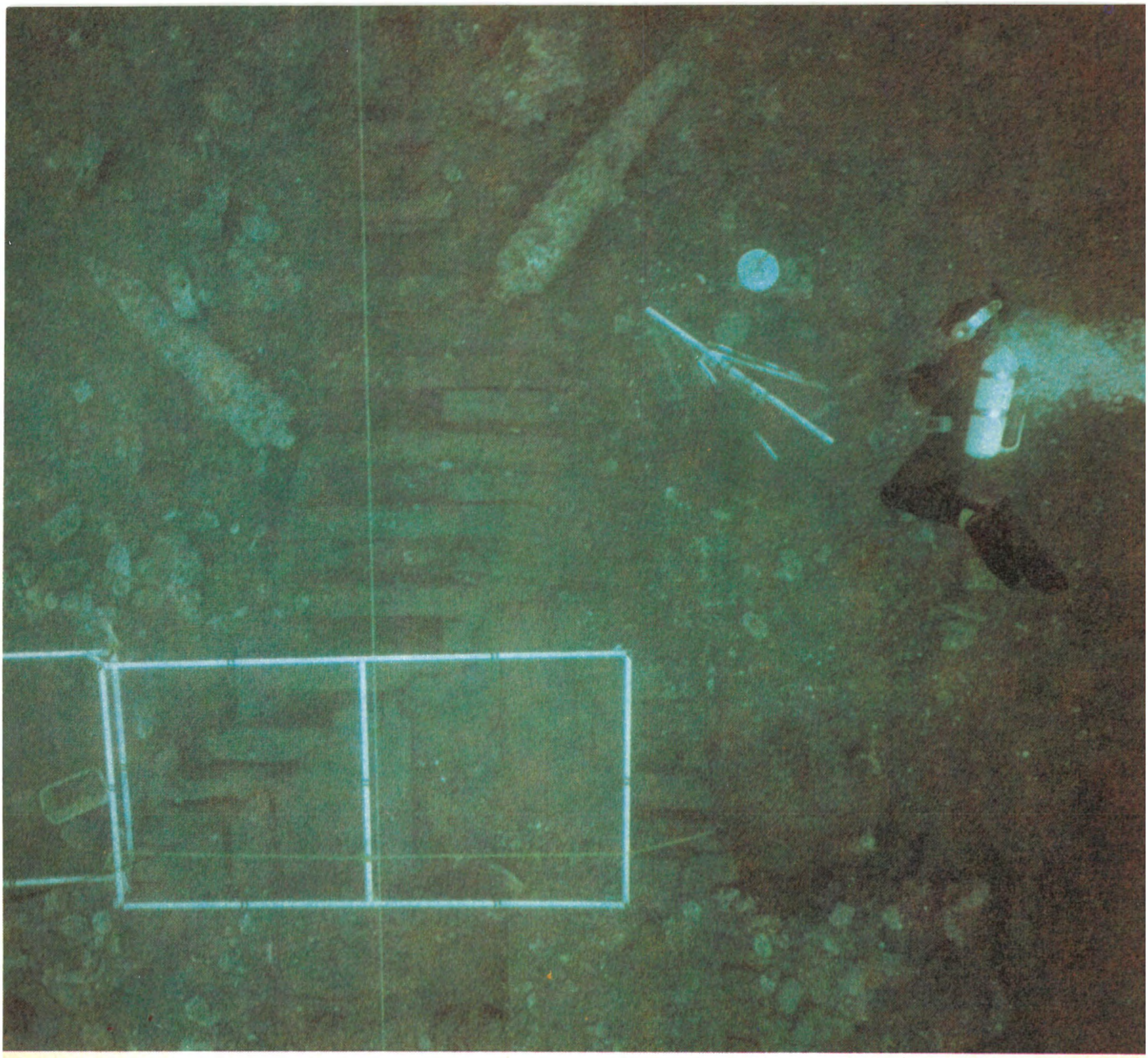


In 20 metres of cold murky water in Bay Bulls, Newfoundland, archaeologists survey the site of a British supply ship [above], probably the H.M.S. Sapphire, sunk in 1696. Aluminum frames, installed over a midship section of the hull, provide a grid for accurately recording features of the wreck, such as the placement of timbers, cannons, or other ship parts and cargo. The underwater camera [right, foreground] aids in this procedure; white identification tags denote the exact location of each piece of planking. The thick overburden of silt covering this wreck is being removed with an air lift, a large flexible hose attached to an air compressor on the barge overhead. This work is being done by the Underwater Research Unit of the National Historic Parks & Sites Branch. So far, about 20 such wreck sites have been surveyed, and two ships have been fully excavated.

Waterlogged Artifacts: The Challenge to Conservation

J.C. McCawley

Wood has been a plentiful and versatile material utilized by man since earliest times. From it were fashioned many things, including shelters, boats, tools, weapons, bowls and a host of other utilitarian and decorative articles. After such objects were lost, broken or otherwise abandoned, they ordinarily perished quickly from the agents of decay. Most burial conditions, whether on land or under water, are generally unfavourable for the preservation of wood and other organic substances; they are subject to deterioration by chemical processes and by attack of many kinds of bacteria and fungi. Many factors determine the nature and extent of wood degradation. These include the type of wood (soft or hard), the period of burial and a number of properties of the burial medium, such as moisture content, degree of aeration, pH, temperature and microbiological make-up.

However, wood does survive over long periods of time, under certain favourable conditions. When the environment surrounding the wood is anaerobic (oxygen free), for example, the destructive power of bacteria and fungi is drastically reduced, and wooden artifacts may be preserved for thousands of years. In marine burial, such conditions can be found at depths where temperatures are low and the water holds little dissolved oxygen. On land, the same favourable conditions are characteristic of bogs and other localities where archaeological wet sites are found. Here the pores of the soil, because they are saturated with water, do not permit entrance of oxygen. Once the original oxygen content of the soil layers is gone, the processes of degradation are slowed considerably. It would be wrong, however, to think that degradation ceases altogether. In anaerobic conditions, wood continues to decay due to anaerobic microorganisms and the hydrolytic action of acids in the soil or, in the case of marine burial, the salinity of the water.

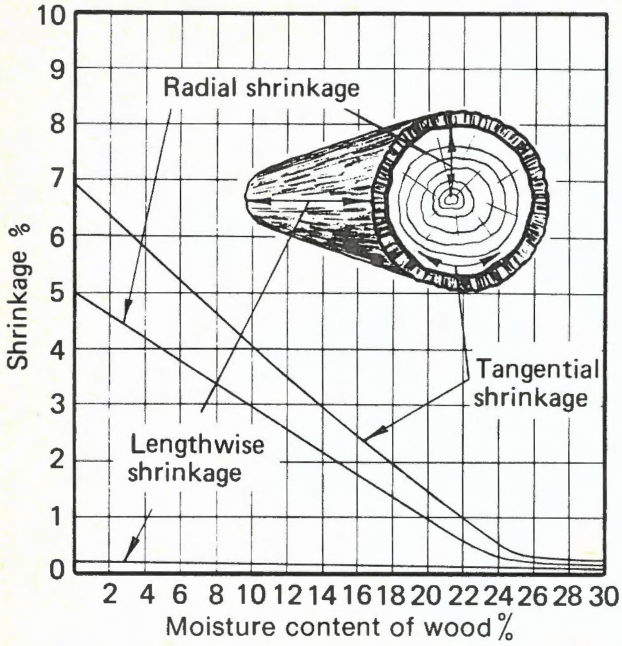
Nevertheless, much wood survives sufficiently intact to allow it to be recovered. Since the upsurge of interest in archaeological excavation which took place in 19th-century Britain and Europe, waterlogged wood has appeared with regularity and in quantity. And, much of it is still lying in the basements of museums awaiting treatment. More recently, a wealth of waterlogged wood and other organic materials has been collected from excavations during the past few years at wet sites on the Pacific coast of North America. This amount of waterlogged material will undoubtedly increase, as archaeologists say that more and more wet sites will be found across the entire continent. Moreover, the growing interest in scuba diving during the past few decades or so, and its utilization and acceptance as an exploration tool, has resulted in the discovery of many underwater sites, especially along sea coasts. Locations are today known of literally hundreds of sunken wooden ships, which await the finances and expertise required to raise and conserve them. For all this historically and scientifically irreplaceable material, the conservation profession must find suitable methods of stabilization and preservation.

The Nature of the Problem

Waterlogged wood when excavated may appear fresh and sound or, if badly degraded, may be soft, spongy, and almost black in colour. As wood becomes more and more degraded, its specific gravity and mechanical strength become lower and its permeability and porosity greater. Moreover, each piece of wood is quite unlike any other, and therefore one should expect it to behave quite differently when recovered and treated.

The mechanical strength of a piece of wood is provided mainly by the walls of the wood cells. In waterlogged wood that is badly degraded, these have normally undergone extensive decomposition resulting in a great loss of mechanical strength. Cell walls, made up largely of cellulose, lignin and hemicelluloses, contain multitudes of submicroscopic capillaries. The cellulose chains of the cell walls contain alternating crystalline and amorphous regions. Water enters the amorphous regions and forms hydrogen bonds with the polar terminal groups, such as hydroxyl (OH), on the cellulose chain. Because water cannot enter the more closed crystalline regions, only adsorption takes place. The wood swells as this take-up of water continues, making available more sites, such as interstitial spaces, for adsorption bonding of water to occur. The amount of water adsorbed will reach an upper limiting value, known as the fibre saturation point (normally between 25-30% in fresh wood), which is dependent upon humidity and, to a lesser extent, temperature. This water, known as hygroscopic water, will remain in the wood after equilibrium has been reached with the ambient humidity. Beyond this point, for example when the wood is soaked in water, free water fills the voids until total saturation takes place.

In badly degraded waterlogged wood, after most of the cellulose and hemicellulose have disappeared, the average diameter of the submicroscopic capillaries has increased, resulting in a corresponding decrease in surface area and producing many more voids to be filled with free water. In waterlogged wood, free water acts first as a bulking agent helping the wood to retain its shape; second, by bonding to the hydroxyl groups of the remaining cellulose, it prevents them from bonding with each other and forcing a shrinkage of the cell wall inwards. This latter function is particularly important since, in waterlogged conditions, hydrolysis of the crystalline regions of the cell wall and the resulting depolymerized cellulose chains make available more polar terminal groups for bonding. Thus, the water is the conserving agent, and the wood will remain reasonably stable as long as it is kept



Shrinkage of wood.

Shrinkage and cracking of waterlogged wood resulting from uncontrolled drying.

wet. However, if allowed to dry, a number of rapid and damaging reactions occur.

Everyone is familiar with the tendency of wood to change its shape by swelling or shrinking with differing humidities. The wood will take up an amount of water, depending on the humidity level of the surrounding atmosphere, until an equilibrium is reached (equilibrium moisture content). In doing so, swelling occurs. When the wet wood is transferred to a drier environment, this water is lost, with accompanying shrinkage, until equilibrium conditions are again reached. However, the exact former dimensions and moisture content of the wood are never reached (hysteresis effect). The magnitude of the dimensional changes are proportional to the magnitude of the humidity changes. With sound wood, and wood that is not too badly degraded, shrinkage occurs in an anisotropic fashion, that is, varying in three major directions. In sound wood, the shrinkage in the longitudinal or fibre direction is generally small, averaging less than 0.5%. This increases to between 3% and 6% for shrinkage in the radial direction, and between 5% and 10% for the tangential direction. Shrinkage and cracking in badly deteriorated waterlogged wood will be less well differentiated than in sound wood. Depending upon the nature of the decomposition, waterlogged wood can decompose completely on drying. Hence, when dried in air, waterlogged wood displays this abnormal behaviour and shrinks, cracks, and warps. Unfortunately, these changes are irreversible. Once degraded wood has dried out, it will not return to its original dimensions. One possible explanation is that the polar groups on adjacent cellulose molecules bond together and are therefore unavailable for future water adsorption. Another equally important cause is the aspiration of pits, which are openings in the cell wall for water transport.

Why do these severe dimensional changes occur? When wood is allowed to dry, the free water is the first to evaporate. In sound wood, this will occur without shrinkage until the fibre saturation point is reached and hygroscopic water begins to disappear. With badly degraded wood, in which the water content can be more than 100% based on the dry weight, the shrinkage occurs well before this point, even at relative humidities as high as 98%. When the structure of the wood is greatly disordered and weakened, the surface tension of the receding water is greater than the strength of the remaining cell walls, and they collapse inwards. Furthermore, as already described, polar groups on the cellulose molecules tend to bond together when water is not present to neutralize the effect. The result is a collapsing inwards of the cell walls. These two factors cause the wood to shrink, crack, twist and warp. We now see that it is this resistance to drying, with the resultant dimensional changes, that makes the conservation of waterlogged wood such a problem.

Approaches to Conservation

The conservation of waterlogged organic materials involves primarily the cleaning and stabilization of objects against further decay. Wooden objects saturated with water must normally be cleaned for two reasons. First, the greatly increased porosity of waterlogged wood and the lengthy burial in environments containing foreign organic materials and mineral products lead to the build-up of considerable extraneous material within the wood structure. This foreign material may act as a bulking agent and restrict shrinkage due to drying, but when conservation is attempted, it prevents the penetration of consolidants.

Second, when a wooden object or wood-related substance such as bark is unearthed, the archaeologist often sees a rapid darkening of its colour. Although the phenomenon obviously takes place when objects are exposed to the air, the specific causes of it are not fully understood. (Archaeologists digging at the Kwatna Site on the central British Columbia coast reported that plant fibre specimens were already unusually dark when excavated, indicating that they may not have been buried quickly but were exposed to the atmosphere for some time during waterlogging.) Cleaning, necessary in order to retrieve the original lighter appearance of such materials, is done in a variety of ways with varying degrees of success. Use has been made of mechanical methods (fine water jets or brushing) and chemicals (acids or sequestering agents).

For many obvious practical and aesthetic reasons, the water in a recovered waterlogged artifact must be removed. The aim of stabilization is to remove it in such

Waterlogged perishable artifacts must be kept in water, often including a fungicide, until treatment. At the CCI laboratory, wooden objects from the Lachane Site are continuously washed with running water for several months before treatment. This removes some of the extraneous material which adheres to the object after centuries of burial.

a way that little or no dimensional changes occur to the wood, and so that the object can be kept at normal museum conditions (typically 65% relative humidity and 20° C temperature). Because wood swells when saturated with water, one must decide whether the object when conserved should have the same size and shape as when newly made or as when found. Experience, I think, shows that we can only attempt to approximate the size and shape when found. Badly deteriorated wood often requires improvement of its mechanical properties, so that it can sustain its own weight and be easily handled. Also, the treatment must leave the wood with an acceptable appearance as regards surface texture and colour. And, the treatment should, if possible, be reversible. Any materials added to the wood should be easily removable in the event that time shows the added materials are in some way damaging the object.

The stabilization method one chooses to use will depend partly on whether one wishes the treated wood to behave as natural wood and be responsive to temperature and humidity changes, or whether the wood is to be altered to such an extent that it no longer behaves like the natural product. In the latter case, it essentially becomes a synthetic material resembling the original wooden object only in appearance and size.

Five basic approaches to the dimensional stabilization of wood are: (1) the total or partial bulking of the spaces within the cell walls, normally occupied by water, with a solid material which prevents collapse and increases the mechanical strength of the wood; (2) the removal of free water in such a way as to avoid normal drying stresses; (3) the reduction of the permeability of wood to water vapour by use of internal or external coatings; (4) the chemical modification of the structural units of wood to reduce its hygroscopicity; (5) the chemical cross-linking of the wood's structural units to restrict swelling or shrinkage and to increase mechanical strength. Of these alternatives, the first two have been most extensively used and studied. It can be seen also that two or more approaches might be included in a single treatment.

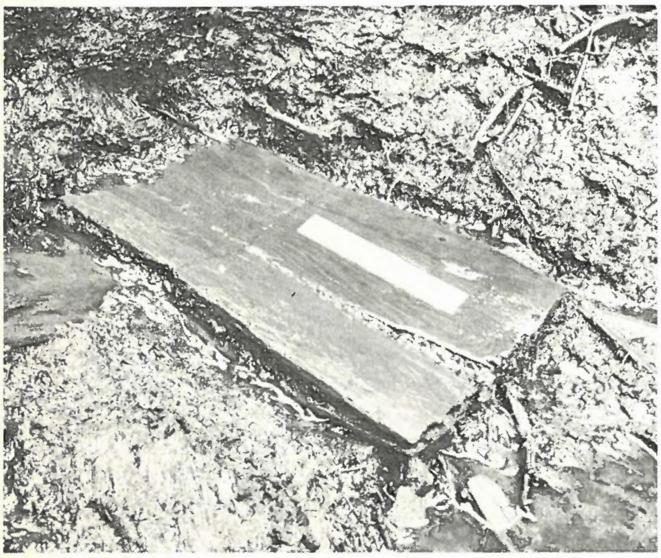
Older Conservation Methods

Little documentation exists which records early attempts to conserve waterlogged wooden objects. Rather, conservators of the past viewed the tendency of wood to shrink and distort as inevitable, and the problem was largely ignored.

In the mid-19th century, the archaeological assistant to King Frederik VII of Denmark, a man named Jørgensen, made reference to the so-called alum method for treating waterlogged wood. This technique, with modifications, was used as the standard waterlogged wood treatment method by the National Museum of Denmark for almost 100 years. Initially, the method involved soaking the wood in a hot (95°-100° C) super-saturated solution of alum (potassium aluminum sulphate, $K\ Al\ (SO_4)_2 \cdot 12H_2O$). The object was boiled in the solution for at least two hours and was then allowed to dry slowly. The aim of this method was to replace the free water in the wood with the solid alum.

Subsequent modifications involved the absorption of linseed oil into the alum-impregnated wood, and then varnishing the dried object to prevent any further intake of moisture. At a later date, the linseed oil/varnish impregnation step was replaced by continuously coating objects with a gelatin "glue" solution. Attempts to use glycerol and glycerol jelly in place of the alum were discouraging, but led to the adoption of an alum-glycerol-water bath for treatment. Later modifications dealt more with finding a suitable surface coating than with replacing the alum. Coatings used included shellac, beeswax, nitrocellulose varnishes, various oils and others.

While many treatments have been successful with the alum method, it is nowadays generally considered unsuitable. Its use was abandoned by the National Museums of Denmark in 1962. The reasons for this are not very difficult to find. Examinations of unsuccessful alum treatments have shown that in many cases the impregnation was incomplete, the alum penetrating only the surface to a depth of a few millimetres. Moreover, alum itself is hygroscopic and dissolves in a small amount of water, so it is easily affected by humidity changes. The addition of glycerol makes this problem worse. Glycerol is significantly hygroscopic, easily taking up moisture in damp surroundings and losing it in dry conditions. Thus the treatment itself encourages dimensional changes and cracking of the wood. The increased absorption of water caused by the glycerol, followed by drying, results in successive stages of solution and crystallization of the



Top to bottom: a waterlogged dugout canoe recovered from a lake at Maniwaki, Quebec, and presently at the CCI for treatment; cedarbark rope from the prehistoric village site at Ozette on the coast of Washington [see page 5]; a collapsed red cedar box in a wet deposit at the Lachane Site, northern British Columbia, where over 400 perishable artifacts were found.

alum. This results in increased cracking and often the migration of alum to the surface where it is deposited as an unsightly white powder. Furthermore, glycerol can impart an undesirable sheen to the surface of an object, and often produces a strong odour. It is also said to increase mould growth.

In treating objects by the alum method, one must also carefully control the humidity of the surrounding atmosphere. Artifacts poorly treated with alum have been recovered by dissolving out the alum with water, dehydrating with acetone, replacing the acetone with white spirit, and then, after heating to 60° C, adding paraffin wax until the bath has reached a high concentration. Reported results of this technique have been quite encouraging.

One common fault of early experimenters with waterlogged conservation techniques was their failure to keep adequate records of treatments. Generally, only hints are left as to what was actually used. Treatments which have been recorded include: the use of a solution of gum dammar in benzol for impregnation, followed by surface treatment with a wax-bitumen mixture; the impregnation with a solution of gum dammar in ethyl ether; and the slow drying of fairly sound timbers, accompanied by surface applications of a mixture of linseed oil and kerosene.

Probably the first application of the use of synthetic polymers took place in 1936, when the American scientist A.J. Stamm, after trying several, found phenol formaldehyde resins to be the best. This was followed by several attempts using cellulose nitrate solutions. Perhaps the most important advancement, in light of present treatments, was in 1956 when Stamm introduced the use of carbowaxes or polyethylene glycols. This date might conveniently be taken as the starting point of modern approaches to conserving waterlogged materials.

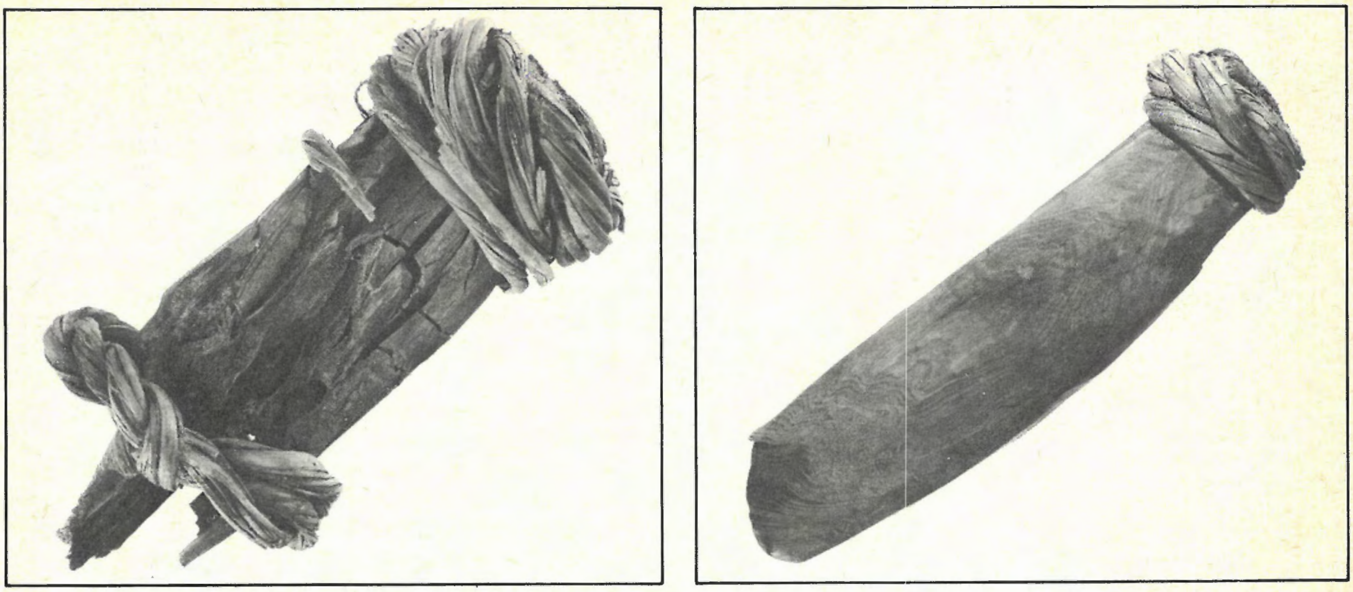
Modern Conservation Approaches

Conservation of an artifact should begin, ideally, the moment it is found in an archaeological site. The object should be kept wet at all times, whether in transport or in storage — at no time should it be allowed to dry out. To prevent continued or renewed deterioration, it should be treated with a biocide. If one knows which treatment method will be used, this can be started while the object is in storage. The example, an object to be treated with polyethylene glycol can be stored in a solution of it.

The practical methods that have been followed over the past decade or so are best discussed within the framework of the five basic approaches listed previously. There are perhaps three major factors which determine the choice and likelihood of success of a conservation method. These are the kind of wood, the degree of decay, and the size of the object. The effects of these parameters will be discussed in the following descriptions of treatments.

[1] *Total or partial bulking*

In this operation, the water which fills the spaces between the cell walls is replaced by a non-volatile solid which prevents collapse and increases the mechanical strength of the wood. This can be achieved in various ways. Solid material can be introduced as a solution in water or an organic solvent at room temperature or at elevated temperatures. Or, if the melting point of the solid is reasonably low, the molten material can be used directly. In the first case, the water or solvent is allowed to evaporate, leaving the solid behind in the wood.



Two wooden wedges from prehistoric wet sites. The wedge on the left was treated with polyvinyl acetate in the field and then allowed to dry out. The other was treated at the CCI with the alcohol-ether dehydration method, using rosin for impregnation.

The ease of penetration depends largely on the size and shape of the molecules and the viscosity and concentration of the liquid. Alternatively, solids can be deposited in the wood by first impregnating it with a liquid monomer or resinoid, which is then polymerized or condensed with high-energy gamma radiation, heat or a catalyst.

A number of methods, which fall into a miscellaneous category, have been tried with varying results. For example, a mixture of stearyl and cetyl alcohols obtained from spermaceti oil, known as Cetalol S.A., has been used. After initial dehydration in ethanol, the wood was kept in a molten bath (60° C) of Cetalol for several days. On removal, the wood twisted and developed cracks. In another experiment, a similar substance derived from spermaceti oil also met with little success. The wood was immersed in molten Jasperol (sulphonated fatty alcohols) for several days, but had an unacceptable soft, waxy appearance after treatment.

Impregnation of wood using electrokinetic techniques has been done in Poland. The piece of wood to be treated was suspended between metal electrodes across which a current was passed. The potential drop between the electrodes encouraged liquids to migrate towards the negative electrode and, in so doing, impregnate the wood with different inorganic materials. These included single solutions and mixtures of water glass ($Na_2O. SiO_2$), calcium chloride ($CaCl_2$), acetic acid (CH_3COOH), phosphoric acid (H_3PO_4) and others. It was also found that the method worked equally well when the solution was replaced with sand saturated with the solution. This enabled in situ treatments at an archaeological site to be carried out. Unfortunately, the promising results reported have not yet been reproduced elsewhere.

Hardening and structural stabilization of wood has been reported following treatment in aqueous solutions of sodium bichromate ($Na_2Cr_2O_7$) and chromium trioxide (CrO_3), which after chemical modification within the wood are deposited as chromium chromate ($Cr_2(CrO_4)_3$) and calcium chromate (Ca_2CrO_4). As a final step, the wood is given a protective coating by immersion in linseed oil. A recent paper describes the successful use of tetraethyl orthosilicate for preserving waterlogged archaeological materials. Two quite common substances, sucrose and sodium chloride, have been shown from preliminary studies to have greater shrinkage-restraining effects than polyethylene glycol.

Finally, concluding this list of miscellaneous methods, is the use of water soluble organic materials such as methyl cellulose, polyvinyl acetate and polybutyl methacrylate. In general, these have not been successful. The degree of penetration is not good and gives little protection against shrinkage and warping. However, there is some prevention of surface checking.

A method that has proved over the years to be excellent for the treatment of small timbers is the *alcohol-ether-dammar resin method.* Derived from the work of B. Brorson Christensen in Copenhagen, this method involves the slow dehydration of the wood using successive changes of ethanol. This is accomplished over a period of several weeks. When dehydration is completed, the alcohol is exchanged for ethyl ether. After being in ethyl ether for approximately two weeks, the wood is placed in a bath of ethyl ether saturated with dammar resin for a further two or three weeks before being allowed to dry. The treated wood usually has a light brown colour and a generally natural appearance. It usually shows only a slight tendency to crack or warp. Occasionally a mixture of dammar resin and rosin (colophony) is used, and results with this are good as well.

Unfortunately, because ethyl ether is extremely flammable and has strong narcotic effects, it is not suitable for use on a large scale without complicated and extensive facilities.

The *polyethylene glycol method* is, at the present time, considered to be the most suitable way of stabilizing waterlogged wood. Polyethylene glycols (carbowaxes) are polymers of ethylene oxide with the general formula $HOCH_2 (CH_2OCH_2)_n CH_2OH$, where n represents the average number of oxyethylene gaps. All polyethylene glycols, except polyethylene glycol 1500 (recently redesignated 540), are designated by a number that approximates the average molecular weight. From the point of view of waterlogged wood, the most useful property of these polymers is that they are all soluble in water and also in many organic solvents. With increasing molecular weight, water solubility, vapour pressure and hygroscopicity decrease, whereas freezing or melting range and viscosity increase. In appearance, they range from clear viscous liquids (lower molecular weights 200-600) to white, waxy solids (higher molecular weights 1000-6000).

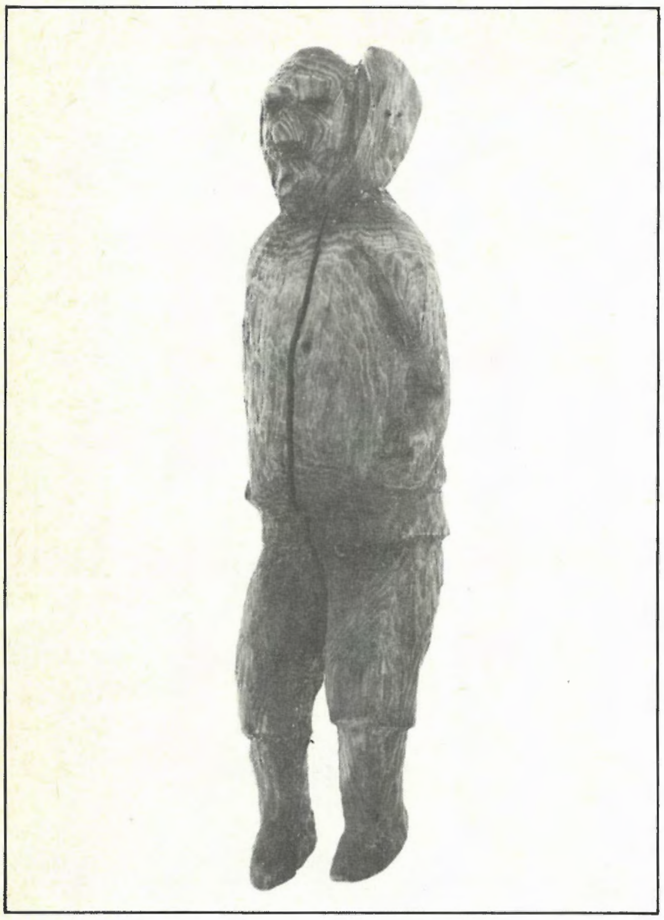
Ease of penetration into the wood depends on the size and shape of the penetrating molecules, which increase with increasing molecular weight. In polyethylene glycol 4000, the size of the molecule is approximately 250 angstroms when it is in stretched form. If the molecule is in coiled form, it could be too large to pass through the pit pores of the wood, and hence penetration would be greatly reduced. More badly degraded wood allows use of higher molecular weight polymers. As a general rule, the less badly degraded is the wood, the lower the molecular weight polethylene glycol must be used. This is particularly true when treating objects fashioned from the heartwood of oak. In the living tree, movement of water ceases in the heartwood and tannins are deposited which prevent decay, therefore, ironically, making treatment more difficult. Eventually, vessels become blocked by growths called tyloses (this occurence is particularly prevalent in white oak, which was widely used for shipbuilding). Iron, which is often present in some quantity in waterlogged wood, also has a preservative effect. When iron compounds are present, they block movement of polyethylene glycols and probably catalyse the depolymerization of the polymers.

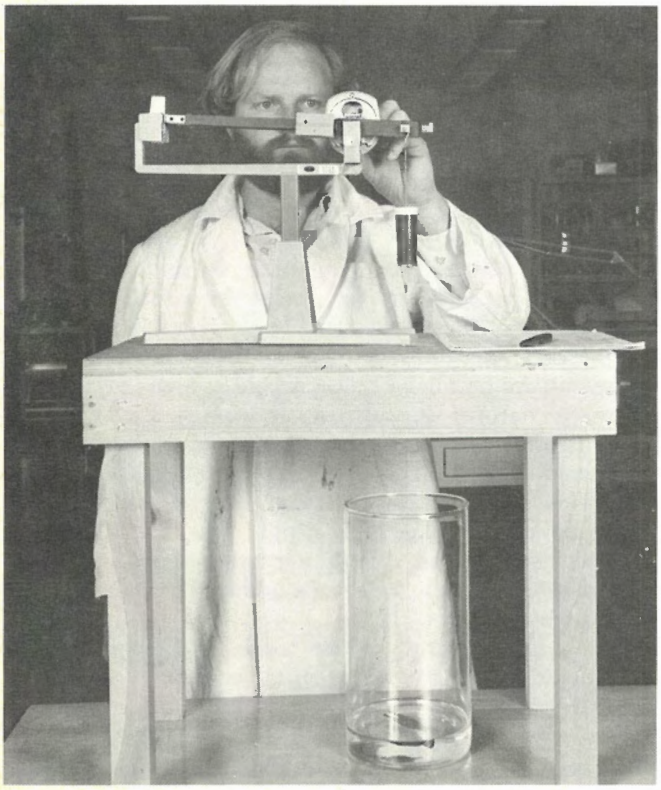
There have been two main approaches to the treatment of wood with polyethylene glycols. One involves spraying the wood constantly with a polyethylene glycol solution. To treat parts of the hull of the Swedish warship Wasa, which was raised from Stockholm harbour in 1961, a 35% solution of the 4000 grade was sprayed onto the oak timbers which were being slowly dried at a relative humidity of around 70%. A mean concentration of about 40% polymer was achieved, the surface naturally being considerably higher. If one disregards, for the moment, the question of how much impregnation actually takes place, the main drawback to this process is the length of time the treatment takes.

The treatment can be speeded up considerably by placing the wood in a heated bath of polyethylene glycol solution. A typical treatment would be to place the wood in a low concentration of the polymer (typically 10%) which is maintained at 60° C. The concentration of the polymer is then gradually increased on a daily basis by additions of the pure material. This can be continued until a sufficiently high concentration of polymer has been obtained. Some experimental work suggests that the treatment is probably completed when a concentration of 70-80% has been reached. During this process, the original volume of water is maintained. Finally, the wood is cleaned of excess polymer and allowed to dry slowly.

Tanks for this process have been fabricated from stainless steel, heavy-duty polyethylene and fibreglass. Copper, zinc, iron and aluminum are not suitable since they can cause depolymerization of the polyethylene glycol.

Impregnation of waterlogged wood with materials such as polyethylene glycol is largely a process of diffusion. That is, water passes out of the wood while the polymer diffuses into it. The rate of diffusion is expressed by the diffusion constant, which is inversely proportional to the molecular weight of the compound. Thus we can say that the time taken for a particular substance to diffuse will be proportional to its molecular weight. Polyethylene glycol 1000 will diffuse approximately 18 times slower than ethanol, which has a molecular weight of 55. Dilute





During consolidation of a waterlogged wooden object, a conservator can periodically measure its specific gravity to check the progress of the treatment. As the water exchanges with other liquids or solids, the specific gravity also changes. This Inuit figurine [top], carved in Dorset style but found in the remains of a Thule house, is from the Grinnell Peninsula of northwestern Devon Island, and dates to roughly 1200 A.D. Although it was excavated from permafrost, the carving can be considered waterlogged with respect to treatment.

Chemical analysis for lignin and cellulose provides an indication of how badly degraded a piece of wood is. Here, a CCI scientist tests for the amount of lignin, which can remain in wood after years of burial, simply by removing the cellulose, easily hydrolyzed by acids, and weighing what is left.

solutions will have a proportionately higher diffusion constant than concentrated solutions, and it is for this reason that treatment is commenced at low concentrations where the diffusion constant of the solution is comparable to that of water. If too high a concentration is used at the beginning, partial dehydration of the wood — and irreparable damage — can occur while the wood is in the treatment bath. This happens when water diffuses out of the wood at a much faster rate than the concentrated polymer solution can replace it. This often leads to consolidation of the surface zones only, and not the interior of the object. High temperatures seem to make this problem worse, especially with sound oak. Similarly, overtreatment, that is, continuation of the treatment until the solution has a high concentration, is also damaging and uneconomic. This tendency results in the wood having a very low water content (less than 10%), which is far less than the ultimate equilibrium water content after treatment (20-30%) when the object is maintained at ambient conditions.

In summary, from the accumulated data of treatments with polethylene glycols, we can say that the condition of the wood dictates which grade of polyethylene glycol can be used. Badly degraded material can be treated with high molecular weight grades, whereas reasonably sound timbers can only be treated with lower molecular weight grades. A molecular weight of around 3000 has been mentioned as the maximum size which will penetrate reasonably sound wood. The lower molecular weight grades are unfortunately quite hygroscopic, and objects treated with these grades are unsuitable for handling and require carefully controlled environments for display.

Although polyethylene glycols are extensively used, their suitability for other than small objects is being questioned. It appears that the size of an object could be the determining factor in whether a polyethylene glycol treatment is successful or not. In large timbers, penetration appears to be confined in many cases to the external zones. Unfortunately, in the majority of examples, a high degree of consolidation appears necessary for lasting stabilization.

The *acetone-rosin method* was developed specifically for the treatment of large, sound, waterlogged oak timbers, which have proved extremely difficult to conserve using polyethylene glycol. The wood is given an initial treatment in hydrochloric acid (3%) in an attempt to remove extraneous deposits and to restore the usually darkened oak to its original lighter colour. After the excess acid has been removed by washing in water, the wood is dehydrated in several changes of acetone. Then rosin (colophony) is added to the bath and the temperature raised to 51° C, the concentration of rosin at this temperature reaching 67%. After treatment, the excess rosin is removed with acetone swabs or fumes.

Dimensional stability of the oak after the acetone-rosin treatment is greatly improved, and there is little or no cracking or splitting. The object is lighter in colour (although not as natural a colour as obtained with the alcohol-ether-resin method), and has a weight approximately the same as before being waterlogged. Polyethylene glycols, on the other hand, leave the wood dark in colour and quite heavy. Preliminary studies using the scanning electron microscope show that, in small objects, the rosin penetrates all of the cells to give good stabilization and strength.

Whether or not the acetone-rosin method can be successfully used for very large timbers is not yet certain. Of obvious concern is the highly flammable nature of acetone. Again, facilities meeting proper safety requirements would be expensive to construct and in many places would require specially designed fire-proof and explosion-proof buildings.

A method involving the *in situ polymerization of monomers* has been a subject of research in recent years. (*In situ* is not used here in any archaeological sense, but refers to what is done to the monomer while it is in the wood.) The waterlogged wood is stabilized by impregnating it with monomers and then polymerizing in situ, either by high energy gamma radiation, by the use of chemical catalysts or by heat. Polymeric systems which have been studied, either for conservation or industrial applications, include styrene/divinyl benzene, vinyl chloride, vinyl acetate/styrene, methyl methacrylate, butyl methacrylate, and 2-hydroxyethyl methacrylate. In a similar way, oligomers of methyl methacrylate and dimethyl siloxane have been used.

Some of the advantages gained by using such a treatment derive from the fact that monomers have low molecular weights; hence the diffusion coefficients of the pure liquid or its solutions are similar to that of water and other solvents. This means that some of the problems encountered in the polethylene glycol method are removed. Similarly, the small size of a monomer makes penetration into the wood easier.

Results of in situ polymerization of monomers to date are quite promising, and usually show greatly improved dimensional stability of the wood with little shrinkage. In some cases, however, the wood has been left with an unacceptable, high gloss. With gamma ray polymerization, the immediate drawback is the very expensive requirement for irradiation facilities. And, the fact that some monomers are not water soluble means that the wood first has to be dehydrated. This could be a problem with large timbers when large volumes of solvents would have to be used.

Impregnation with synthetic resins involves the use of low molecular weight resin systems, such as urea-formaldehyde, melamine-formaldehyde (Arigal-C) and phenol-formaldehyde. The condensation products formed have been shown to reduce the shrinkage and increase the strength of the wood. The Arigal-C method, however, which is perhaps the best known, often causes the treated wood to have a whitish, bright appearance and does not always prevent splitting and cracking.

A recent and rather novel treatment involves soaking the wood in a sugar solution, then chemically modifying the sugar to produce an aqueous resin solution. The addition of a catalyst, followed by heat curing, results in the formation of a water insoluble, inextractable material within the wood. The results are reportedly good.

Resin systems have been used somewhat successfully in treating waterlogged wood. However, the short time required for condensation to occur is not suitable for large timbers where impregnation would be slower. This problem could disappear with the continuing industrial advances being made in the area of resin systems.

[2] *Removal of free water*

Removing free water from wood must be accomplished in such a way that drying stresses are avoided. The damage caused to wood by the receding water surface on drying is due to the high surface tension of water. Attempts have been made to prevent this damage by replacing the water with a solvent with a lower surface tension and then allowing the solvent to evaporate. Ethyl ether was first tried and, with very small objects, was somewhat successful. However, shrinkage did occur and the method was altered to include a consolidating agent — the alcohol-ether-resin method. A much more recent attempt using commercially available dewatering fluids was reported to be successful, but an evaluation by other workers suggested that dewatering fluids did not prevent shrinkage and deformation, and that any success had been due to the inherent soundness of the wood.

An alternative method is to replace the water with a liquid which, when frozen, can be removed by sublimation under vacuum. The essential feature is that sublimation takes place without a liquid phase being present. Trimethyl carbinol was the liquid of choice by several laboratories, but the results were not promising. Cracking and checking appeared on many artifacts so treated.

Freeze-drying, a technique much used in the food industry, is now being used more and more in the conservation of waterlogged wood. In the freeze-drying method, no initial replacement of water is necessary. The water is simply sublimed away under vacuum. This requires that the vapour pressure of the water above the ice surface is less than that at the ice surface, a condition that can be achieved by the use of vacuum and a condenser. To collect the sublimed water vapour, the condenser must be considerably colder than the wood itself. To obtain a practical rate of sublimation, it is also necessary to heat the wood during the treatment. This is necessary to replace the latent heat of sublimation used in the conversion of solid ice to water vapour.

Initial freeze-drying experiments were reasonably successful, although the wood still suffered some shrinkage and cracking. This is due to the strain caused by rapid freezing of the wood (water undergoes a 12% volume increase on freezing) and the damage caused by the absorption of atmospheric moisture after the treatment. These problems were removed to a great extent by soaking the wood before freeze-drying in a 10% solution of polyethylene glycol 400. A 10% solution undergoes a volume increase on freezing less than half that of water. This, combined with the solution's low vapour pressure and low surface tension, greatly reduces damage. Results have generally been good, and work assessing the efficacy of this method for large timbers is in progress.

[3] *Internal or external coatings*

The use of surface coatings is aimed at reducing the permeability of wood to water vapour. Alternatively, partially coating the inner surfaces with so-called water repellents, such as waxes, has been tried in attempts to achieve the same effect. A wide variety of materials, from linseed oil to epoxy resins, have been used, but the results are generally unsatisfactory. The rates of swelling and shrinkage are reduced, but in the end the amount is not much altered. No dimensional stabilization is achieved.

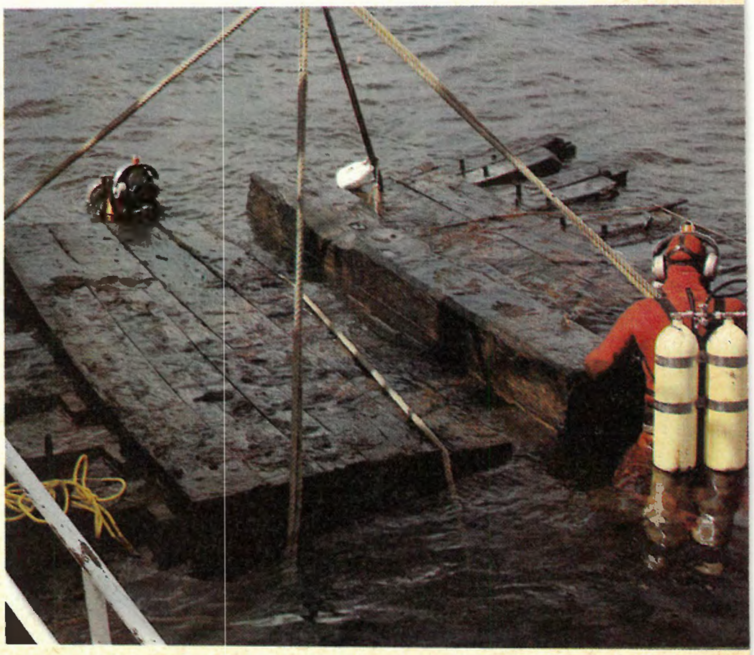
[4] *Reduction of the natural hygroscopicity of wood*

Attempts have been made to reduce hygroscopicity by chemically modifying the cellulose and lignin molecules. Acetylation has shown some success in industrial applications, although some of the success is thought to be due to bulking effects caused by interaction with the cell walls. Similar experiments done in the CCI's Conservation Processes Research laboratory on badly degraded wood were completely unsuccessful, probably because of damage caused to the wood structure by the acetylating agent. It appears likely that this method will not be successful until new and less powerful treating agents are found. One alternative might be to reduce the hygroscopic nature of the impregnating agents (for example, polyethylene glycol 400) before treatment. This has apparently been tried with isocyanates.

[5] *Chemical cross-linking*

In this method, it is assumed that chemically linking the cellulose chains will prevent swelling due to moisture increases and will, therefore, confer dimensional stability to the wood. Formaldehyde, ethylene oxide and other materials have been tried, but with only limited success,

Cables creaking, the three-ton rudder of the French frigate Machault is slowly raised from shallow water in the estuary of the Restigouche River near Campbellton, New Brunswick [above]. Built in 1758, the Machault carried supplies for French troops and was deliberately scuttled in 1760 when her passage was blocked by a British warship. Tidal mud apparently covered the vessel soon after, for it is remarkably well preserved. Massive portions of the hull, such as this midship section [below], were raised in one piece. The recovered cargo includes barrels of salt pork [left], glassware and fine porcelain, as well as military supplies such as cannonballs and other munitions. These items, and portions of the vessel itself, will be housed in an Interpretation Centre to be built near the wreck site by the National Historic Parks & Sites Branch.

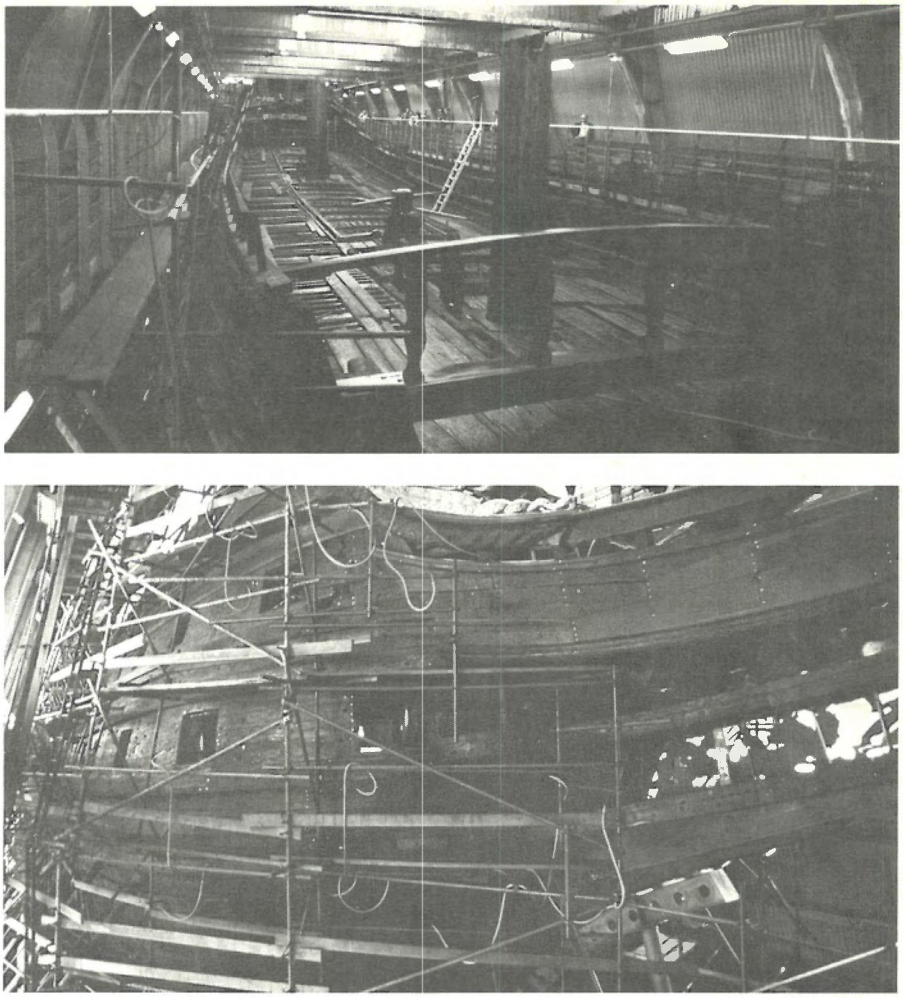


even in sound wood. This, as in the hygroscopicity reduction experiments, is due to the extreme conditions required for the reactions to occur.

The Challenge of Waterlogged Materials

For the past few years, the status of conservation research has been hovering somewhere between that of a "kitchen art", complete with a book of established recipes, and that of a legitimate science. It is now becoming more and more apparent that to hope for any lasting success with conservation problems such as waterlogged wood, we must seek a far deeper understanding of the materials themselves as well as of the physical and chemical processes involved in their deterioration and preservation.

While much of the fog surrounding many conservation difficulties has been cleared away by research so far, imposing problems have yet to be overcome. For example, while there is no great difficulty involved in successfully treating small artifacts, quite formidable problems arise when one is required to treat very large



The Swedish warship Wasa, which capsized in Stockholm harbour at the outset of her maiden voyage in 1628, is the largest single amount of waterlogged wood ever recovered. Raised in 1961, the 70-metre (230-foot) vessel presents a formidable task to conservators at the National Maritime Museum of Sweden — roughly 750 cubic metres [25,000 cubic feet] of material to be preserved. The time-consuming work, still proceeding, has entailed a variety of methods including spraying portions of the hull and upper deck [top] with a solution of polyethylene glycol while the timbers are slowly dried. Orange hoses snaking throughout the bow section [bottom] are part of a sprinkler system for keeping parts of the ship wet until they can be treated.

and badly deteriorated timber structures such as ships. Objects of this size present practical problems in the design, construction and acquisition of proper facilities. Large objects tend to decay to varying degrees at different depths, causing impregnating solutions to diffuse at quite different rates in different parts of the structure. Even before treatment, storage presents headaches; the wood must be kept wet, or perhaps even frozen, requiring much space and equipment. Cost, too, is a crucial factor. An estimate of the cost of polyethylene glycol needed to preserve a ship similar in size to the Wasa (25,000 cubic feet of waterlogged wood) comes to around $3 million at today's prices. This does not take into account tanks, buildings, salaries, and equipment required to complete the job. Conservators, in general, would prefer that large wooden objects be left in place until the money and methods to treat them properly are found.

Yet, if we consider it a worthwhile aim to preserve those aspects of our heritage which are being discovered at marine and other wet sites, we must be prepared to spend time and money to find faster, better and more economical ways of conservation. This article has by necessity been a much simplified account of the problems. However, I hope it has shown that they are as equally complex and demanding as any problems encountered in industrial or academic fields. Because they are, we must use expertise and techniques as sophisticated as those used in other fields. The Canadian Conservation Institute, in recognizing this, is employing scientists such as chemists, biologists and physicists to work closely with the archaeologist and conservator in an attempt to solve some of the problems described. It is thought that by first understanding the material, we will better understand the problems. From this, we can then more meaningfully assess the efficacy of existing conservation processes and develop better alternatives.

J.C. McCawley is Chief of the Conservation Processes Research Division at the Canadian Conservation Institute.

Suggested Reading

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IICHAW. (1971) *Conservation of Wood Objects.* Vol. 2, 2nd ed. The International Institute for Conservation of Historic and Artistic Works, London.

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CCI News

TECHNICAL BULLETIN No. 4, published by the Canadian Conservation Institute, will be available in March. Prepared by Mary-Lou Florian, biologist with Conservation Research Services at the CCI, this bulletin describes the structural, physical and chemical characteristics of organic materials containing either collagen or keratin proteins. The nature of the deterioration of these materials — bone, teeth, skins, hair, horn and feathers — is stressed. Technical Bulletins, dealing with specific topics of concern to conservators and museum personnel, are published at irregular intervals by the CCI. They are available free on request, in French or English. See page 31 for list.

Graffiti, old and new, at Writing-On-Stone Provincial Park in Alberta.

THE TRAVELS OF CHARLES HETT, Chief of the CCI's Archaeology and Ethnology Division, have led him to many a remote corner of our far-flung land. On a three-week **ARCHAEOLOGICAL CONSERVATION FIELD SURVEY** this summer, Hett managed to pass through a number of important site areas from the southernmost prairies to the High Arctic before returning to Ottawa. The trip was undertaken to assess the extent of field work which will be required at various sites in the future, and to plan treatments.

Accompanied on the first part of the trip by John Taylor of Analytical Research Services, Hett examined rock art in southern Alberta, noting severe deterioration at Writing-On-Stone Provincial Park. Previously unrecorded damage by burrowing wasps was observed underlying portions of petroglyphs and pictographs there. Rock surfaces in many areas are in immediate danger of falling off; some have been lost recently, partly by loss of the loose top surface and partly by rock falls. Areas readily accessible to the public suffer vandalism. There is no single solution to the complex problems of slowing deterioration caused by such a variety of elements — geological, biological and human — but some of the most severely endangered surfaces might be best preserved by removing them from the decayed rock to be displayed indoors.

From one of the hottest summer regions of Canada, Hett continued on to the High Arctic, stopping first at the site of a stone house on a small island to the east of Melville Island. There he assisted a survey being conducted by the Prince of Wales Museum (Department of Natural and Cultural Affairs, Northwest Territories, in Yellowknife). Erected by Captain Kellet of H.M.S. Resolute in 1855, the house was intended to provide a cache for possible survivors of Sir John Franklin's expedition or for future explorers. Today only a pile of debris within roofless walls remains. The ransacking of such stores has been done by polar bears, according to reports of visitors over the years, but in more recent times souvenir hunters must be regarded the most active predators on these historically important sites.

Nevertheless, enough remains at this site to represent a unique record of European man's early attempts to explore and survive in this harsh environment. Tin cans still bearing stencilled inscriptions and still containing food have been preserved, as well as clothing and footwear. The clothing of Royal Officers can be found in museums, but rarely the clothes with which the ordinary British seaman of 1850 was expected to endure the rigours of the Arctic climate. Although deterioration of these artifacts is slowed by low ambient temperatures, corrosion continues, and extremely careful excavation

Two views of Captain Kellet's stone house in the High Arctic.

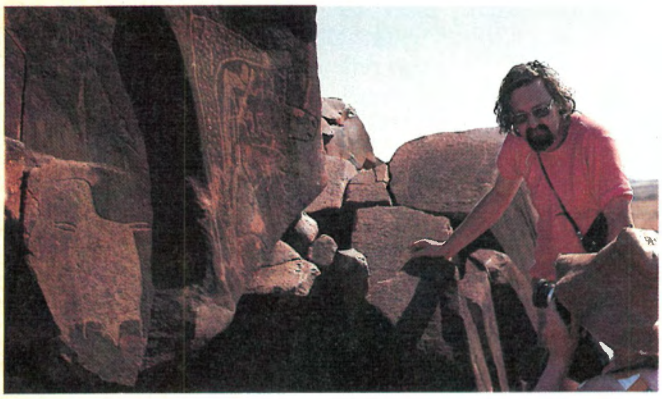
techniques are imperative. Moreover, since the site is on a watercourse and is poorly drained, it is undoubtedly waterlogged when not frozen.

The survey team was accompanied by a rather remarkable dog, loaned by the Polar Bear/Dog Research Institute in Yellowknife. Among his more notable exploits, he managed to make a polar bear reconsider whatever intentions it might have had about venturing onto the site. Later, raiding his own cache of food, this extraordinary canine gulped down some 25 lbs. of frozen fish and a custard pie at one sitting.

From the site of Kellet's stone house, Hett travelled east to tiny Beechey Island, where he completed a project by setting up replicas of two wooden grave markers removed the previous year. Members of Franklin's ill-fated expedition of 1845-1848 and later rescue parties are buried on Beechey. The replicas were molded and cast in the CCI's Archaeology Laboratory. This project was initiated two years ago by the Government of the Northwest Territories. See *CCI Journal* 1:8,9 (1976).

At Port Refuge on the Grinnell Peninsula of northwestern Devon Island, Hett visited excavations being carried out by the Archaeological Survey of Canada under the direction of Dr. Robert McGhee. From these sites, which date from the earliest paleo-eskimo occupations (*ca.* 4,000 years ago) to the Thule period (*ca.* 500 years ago), pieces of wood, ivory, skin and other organic materials with soil matrix were collected for analysis at the CCI laboratories.

Since the state of preservation and the causes of deterioration of each material at a site vary enormously, conservators can provide proper services to field archaeologists only by careful examination of materials and environments. The cooperation of archaeologists in this essential conservation field work is always greatly appreciated.



Inspecting petroglyphs in the Dampier region, northwestern coast of Australia.

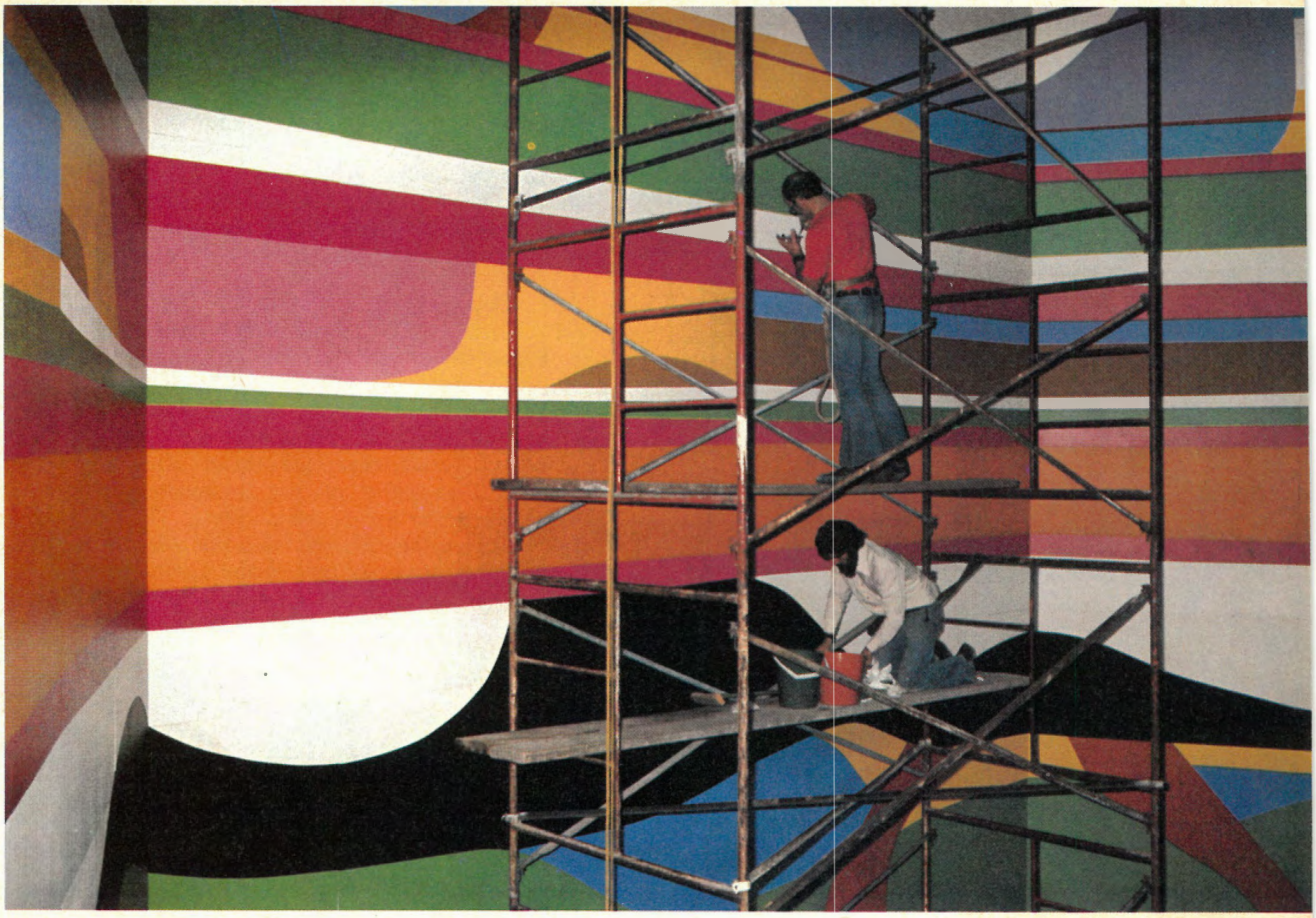
Tracing a rock engraving (with a felt-tip marker on polyethylene) at the Turtle Pool Site, near Tom Price, Western Australia.

Two papers were presented by members of the CCI's Analytical Research Services staff at the **24TH CANADIAN SPECTROSCOPY SYMPOSIUM,** held in Ottawa during October 23-26. Marilyn E. Wheeler and R. Scott Williams contributed *Diamond Cell Infrared Spectroscopy in Art and Archaeological Conservation Research. Microscopical Studies in Art and Archaeological Conservation Research* was presented by Ian N.M. Wainwright.

In **QUEBEC CITY**, a temporary laboratory of conservation was established during the summer of 1977. For the present, it is housed at the Archives of the Ursulines of Quebec, rue Donnacona, where a few years ago the National Museums of Canada subsidized and equipped a small laboratory. The Ursulines Convent is reorganizing its museum in order to display their treasures to the public, and to highlight the activities and history of the Ursulines since their arrival in Quebec. A team of conservators is now undertaking the task of restoring the large collection of the institution. Conservation treatments will be mainly in the fields of easel paintings, polychrome sculptures and paper. It is hoped that this temporary conservation facility will eventually, with adequate staff and quarters, become the Quebec Conservation Centre.

AUSTRALIAN ROCK ART was the focus of an international conference in September, held in Perth, Western Australia, under the sponsorship of the Institute for the Conservation of Cultural Materials. CCI scientists John Taylor and Mary-Lou Florian attended the Workshop on Rock Art Conservation, which included a one-day Seminar at the Western Australia Museum followed by a 10-day field trip to examine sites and conservation work in progress. Papers on various aspects of rock art, such as recording, interpretation, site management and conservation, were presented by researchers from Australia, South Africa, Lesoto, India and Canada.

Since the problems of rock art deterioration and conservation in many parts of the world are quite similar, both the seminar and the field trips proved most interesting and informative to participants. Western Australia, an area of roughly 2.5 million square km, has numerous aboriginal rock paintings and engravings. Some, such as those in the Dampier area, are thought to be as old as 17,000 years. The field trip included many sites where stabilization and preservation work is underway. In the Bolgart area, for example, are engravings on which lichen removal and control experiments are being conducted, and at other places such as the Walga Rock site, the threat of damage by brush fires is being dealt with by the removal of surrounding vegetation. Fences have been erected around some sites to help reduce damage by animals and humans, and experiments aimed at the removal of modern-day graffiti and industrial grime are in progress. The visitors, travelling via a sometimes cantankerous bus and camping in the bush, were able to see numerous examples of paintings, engravings, stone arrangements, shell middens and ochre mines in 14 major site areas. The trip covered roughly between 2,500-3,000 km.



CCI conservators at the National Arts Centre, Ottawa.

CCI FINE ARTS CONSERVATORS surface cleaned and inpainted the huge mural *Homage to Robert F. Kennedy* at the National Arts Centre in Ottawa this past July. The mural, by William Ronald, has graced the foyer of the NAC since 1968, and had accumulated considerable surface grime from finger smudges, coffee splashes, cigarette smoke and the like. The time-consuming work was done by Robert Arnold and Donald Murchison, shown on the scaffold, and Peter Vogel, Sandra Lawrence and Katharine Woodgate-Jones.

PHILIP R. WARD has been appointed Director of Conservation Services at the Canadian Conservation Institute, effective September 26, 1977. Mr. Ward comes to the CCI from the British Columbia Provincial Museum, where he served as Chief Conservator since 1966. Prior to that, he worked with the British Museum in the Department of Oriental Antiquities.

Conservator **ROBERT BARCLAY** studied musical instrument conservation under Freidemann Hellwig at the Germanisches Nationalmuseum in Nürnberg this past spring. During the 10-week period, Barclay assisted in the restoration of an 18th-century French harp (by Cousineau of Paris) and produced life-sized technical drawings of other instruments in the museum's collection. The museum's laboratory is well known for its conservation work as well as its publications of drawings and specifications of a great variety of early instruments. Barclay is a member of the CCI's Furniture and Wooden Objects Division staff.

BIRCHBARK CANOES, which may be found in some ethnographical collections, have rarely, if ever, been recovered from archaeological excavations. Archaeologist David Arthurs (with the Ontario Ministry of Culture and Recreation, Thunder Bay) found one in 1976 while conducting a survey at the head of Brunswick Lake, some 80 km southwest of Kapuskasing, Ontario. Possibly one hundred years old, still bearing the markings of a Hudson's Bay Company trading post, the canoe is in an extremely fragile state. It poses formidable excavation problems. In August, 1977, Robson Senior from the CCI's Archaeology and Ethnology Division visited the site to determine the conservation work which would be necessary. Freeing the canoe from the thick layer of moss in which it is embedded presents the greatest difficulty; moss tendrils have penetrated the bark and, in places, anchor it to the ground. The cedar gunwales and ribs, buried deepest, are decayed and fragmentary, requiring in situ preservation. Because of such conditions, the canoe has not yet been moved. It has been suggested that the large craft (about 18 feet) might best be excavated in pieces. Some pieces have already been removed or disturbed — the canoe is located on a portage route used for many years.

Record rainfall this September caused extensive flooding of the historic reconstruction of **OLD FORT WILLIAM** at Thunder Bay, Ontario. Built on a flood plain at a bend in the Kaministikwia River, the Fort was inundated early on the morning of September 9th. Water at the site rose an average of five feet in less than two hours. Responding to

Old Fort William, Thunder Bay, Ontario, on September 9th.

a request for help from the Fort's administrators, three CCI staff members were at the scene within 24 hours to advise on how to best save the mud-covered furniture, artifacts and archival materials. A number of the more severely damaged objects were returned to the CCI's Ottawa headquarters for treatment. The full extent of the damage is yet unknown, although it appears to be less than initially suspected. The massive clean-up job will continue for some months, but the Fort is expected to reopen on time next summer.

A research project on the **COLOUR PHOTOGRAPHY OF FLUORESCENT PHENOMENA** from works of art has been completed by **WILFRED BOKMAN** of Analytical Research Services at the CCI. A broad range of materials used in painting, such as pigments, binding mediums, waxes and varnishes, will emit visibile fluorescence when examined under ultraviolet light. Colour and intensity of the fluorescence is largely determined by the age of the painting. The image produced is often quite different from the original composition, reflecting disguised repairs and earlier restorations. Bokman has successfully recorded such fluorescent images on film with true colour fidelity. The technique will enable conservators to better evaluate a work of art before restoration treatment is begun. The results of this research will be published in the near future.

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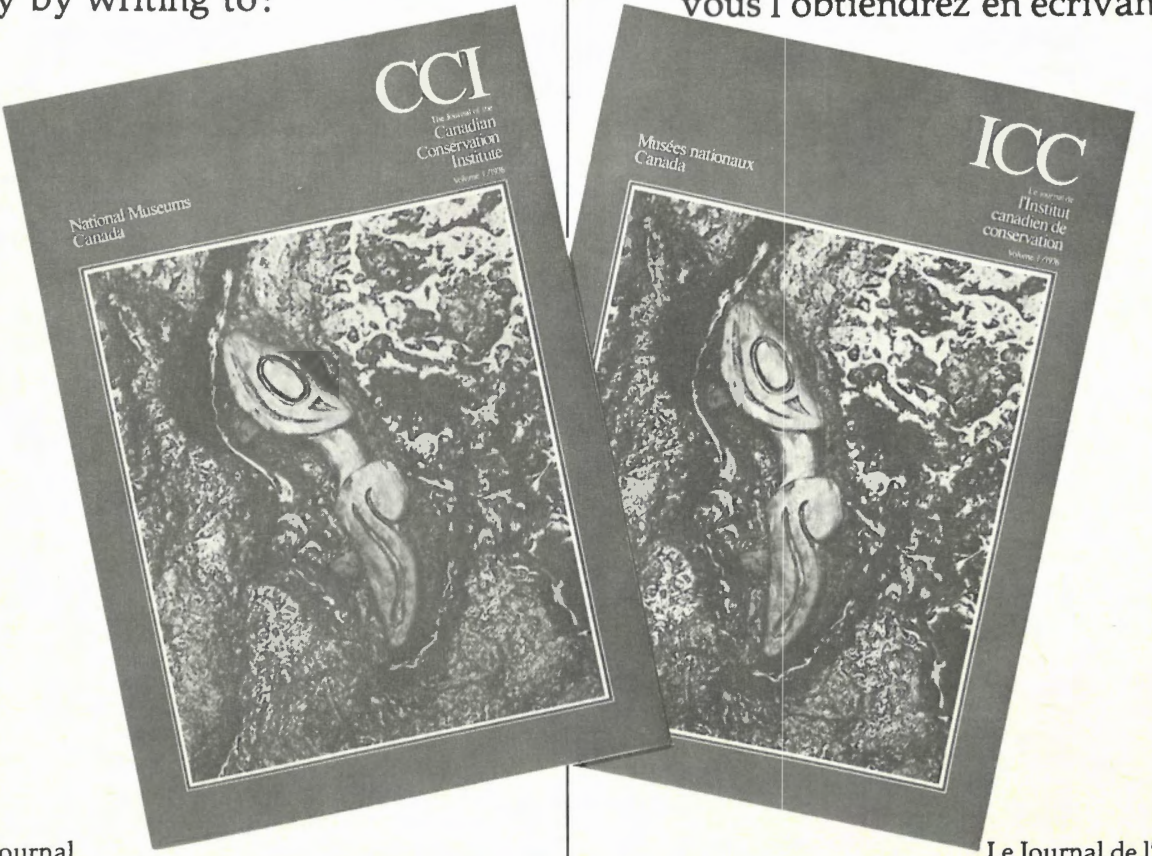

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Glossary

Definitions of these terms are given with specific reference to the ways in which they are used in the text.

absorption. Penetration of one substance into the inner structure of another. See *adsorption.*

acetylation. A form of chemical modification, as when cellulose becomes cellulose acetate. Acetylizing a cellulose molecule reduces its tendency to adsorb water.

adsorption. Adherence of one substance to the surface of another. See *absorption.*

ambient. Surrounding; environmental conditions that exist in the immediate vicinity of an object.

amorphous. Without a characteristic structure; shapeless, formless, non-crystalline. All liquids are amorphous, as are some solids, such as glass.

anaerobic. Not aerobic; that is, occurring without oxygen.

angstrom. A unit of length equal to one ten millionth of a millimetre. It is widely used for stating distances between atoms.

Canadian Shield. A vast expanse of Precambrian gneisses and granites, 1,771,000 square miles in area, comprising most of Quebec and Ontario, northern Manitoba and Saskatchewan, and more than half of the Northwest Territories. In the south it extends into the United States to form the Adirondack Mountains of northern New York and the Superior Upland of Wisconsin and Minnesota.

cellulose. The main component of cell walls in all plant tissue, and thus the most abundant organic material in the world. It consists of long chain-like molecules and microfibrils which are cemented together by amorphous lignin.

crystalline. Having a characteristic shape because the atoms of the material are arranged in a definite pattern. Salt, like most solids, is crystalline.

cytoplasm. The liquid living part of a cell found inside the cell wall.

fibre. Long thick-walled cells in the wood of hardwoods which provide mechanical strength. They are found in other types of plants as well.

hemicellulose. The incompletely polymerized (smaller) form of cellulose.

hydrolytic action (hydrolysis). A chemical change in which water reacts with another substance to form one or more new substances.

hygroscopicity. The tendency of a substance to adsorb moisture from the air.

hyphae. Thread-like filaments in the vegetative, nutrient-absorbing part of a fungus.

hysteresis effect. Derived from the Greek word meaning "to lag behind"; hysteresis in wood means that it takes up water faster than it will give it off.

lignin. The amorphous material which holds together the microfibrils of cellulose in cell walls.

microfibrils. Groups of long chain-like cellulose molecules coiled together.

middle lamella. The layer of intercellular material, mainly pectin, which cements together adjacent plant cells.

monomer. A molecule or simple substance which can be converted to a larger, more complicated, chain-like structure by polymerization. Monomers, in liquid form, become solid when polymerized.

pectin. A group of complex carbohydrates which occur in plant cell walls; the main constituent of the middle lamella.

pH. A number expressing the acidity or alkalinity of an aqueous solution. Values range from 1 to 14: 1 is most acidic, 7 is neutral, and 14 is most alkaline.

polarity. The property of a molecule that is or can be electrically charged. One end of the molecule is positively charged (attracting pole), and the opposite end is negatively charged (repelling pole).

polymer. The product of polymerizing a monomer. Polymerization may be thought of as solidification which, when done to a monomer in wood, provides bulking for structural strength.

sublimation. The direct change of a substance from one physical state to another (solid to vapour, for example) without passing through the intermediate (liquid) state. Ice sublimes to water vapour without appearing as liquid water in the freeze-drying process.

tannin (tannic acid). A complex, astringent, dark brown substance found in tree barks and other plant parts. Tannins are used for tanning leather.

tracheids. Long thin cells which comprise the major part of the wood of softwoods. They transport minerals and water, and provide mechanical support.

vessels. Tube-like series of large cells in hardwoods which transport water.

viscosity. The internal resistance to flow of a fluid. For example, molasses has much greater viscosity than water.

CCI TECHNICAL BULLETINS

1. *Relative Humidity: Its Importance, Measurement and Control in Museums* by K.J. Macleod.
2. *Museum Lighting* by K.J. Macleod.
3. *Recommended Environmental Monitors for Museums, Archives and Art Galleries* by R.H. Lafontaine.
4. *Common Artifact Materials of Animal Tissue Origin* by Mary-Lou Florian.

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Waterlogged portion of the Lachane Site,
Prince Rupert Harbour, British Columbia.

Partie saturée d'eau du site Lachane,
à Prince Rupert Harbour, en Colombie-Britannique.