TECHNOLOGIES FOR SURVEY, IDENTIFICATION, NAVIGATION, EXCAVATION, DOCUMENTATION, RESTORATION, AND CONSERVATION

Preliminary research undertaken carefully before any project can save time and money, and also provide a focus for applying technologies in the field and a basis for evaluating cultural significance. Developments in various kinds of archival technology, for example, can make record searches more efficient and cost-effective, although they have not yet been brought to bear on the types of widely scattered information of value to underwater archaeologists and maritime preservationists.

As noted under Major Issues, underwater archaeologists require a substantial array of technologies to work in often difficult and perilous conditions. These help them find, record, and recover components of submerged cultural sites and cope with formidable limitations on breathing, seeing, moving, and communicating in frequently cold, dark, rough, and turbid environments.

Identification and Survey

Surveys made with the first three of the four following remote sensing methods result in electronic records, patterns of images, or signals in either analog strip charts or digital records. These images indicate both normal and anomalous bottom and sub-bottom phenomena. As in land archaeology, the character of sources of anomalous signals can only be determined through examination in situ. It is important for underwater archaeologists to continue building a "catalog" of representative signals matched with specific anomalous image sources in order to examine and test new underwater contexts such as estuaries and deep water more effectively and efficiently.

The side-scan sonar sends out acoustic frequency signals from a torpedo-shaped towfish located beneath a survey ship. Reflected signals received by the towfish then travel through the tow cable, and are processed on board the survey vessel in a graphic recorder, which produces hard-copy output. They can also be recorded on magnetic tape for post-processing and analysis. The signals produce excellent images of the floor's topography, including structures and shipwrecks, but cannot detect materials covered by sediments. The side-scan sonar can cover wide areas of the ocean bed, enabling the quick and accurate mapping of such geological phenomena as drowned river systems. It is portable, battery-powered, and can be operated from small boats to enable searches in difficult or remote locations.[83]

The *sub-bottom profilers* uses low-frequency sound (3.5 to 12 kilohertz) to penetrate ocean bottom sediments. It directs acoustical signals downward beneath its towing vessel. Where different layers of sediment meet, some fraction of the incident acoustic energy is reflected to the vessel, while the rest continues downward. The device generates a cross-sectional view of the oceanfloor on strip charts, revealing sediment layers and underlying bedrock. Buried hulls show up as localized anomalous reflections below the bottom. Resolutions of less than a meter are possible. Sub-bottom profilers, designed originally for use in deep water can now operate in as little as 3 meters of water. Because they cover only narrow paths, they must make many closely spaced sweeps per survey tract.

Magnetometers sense magnetic field anomalies created by ferrous materials on the oceanfloor. Therefore they can only locate shipwrecks and other historic sites containing such metals. Their major shortcoming is that they must remain relatively close to their target because its magnetic field attenuates rapidly as the distance between them and magnetometric sensors increases. Magnetometers cannot easily trace weak signals or anomalies, such as those detected from under sediments, to their sources. Greater use

[83] C. J. Ingram, "High-Resolution Side-Scan Sonar/Sub-bottom Profiling to 6,000 Meter Water Depth, " paper presented at the Pacific Congress on Marine Technology, Hawaii, Mar. 24-28, 1986,

[84] Milton B. Dobrin, *Introduction to Geophysical Prospecting* (New York, NY: McGraw-Hill, 1976.)

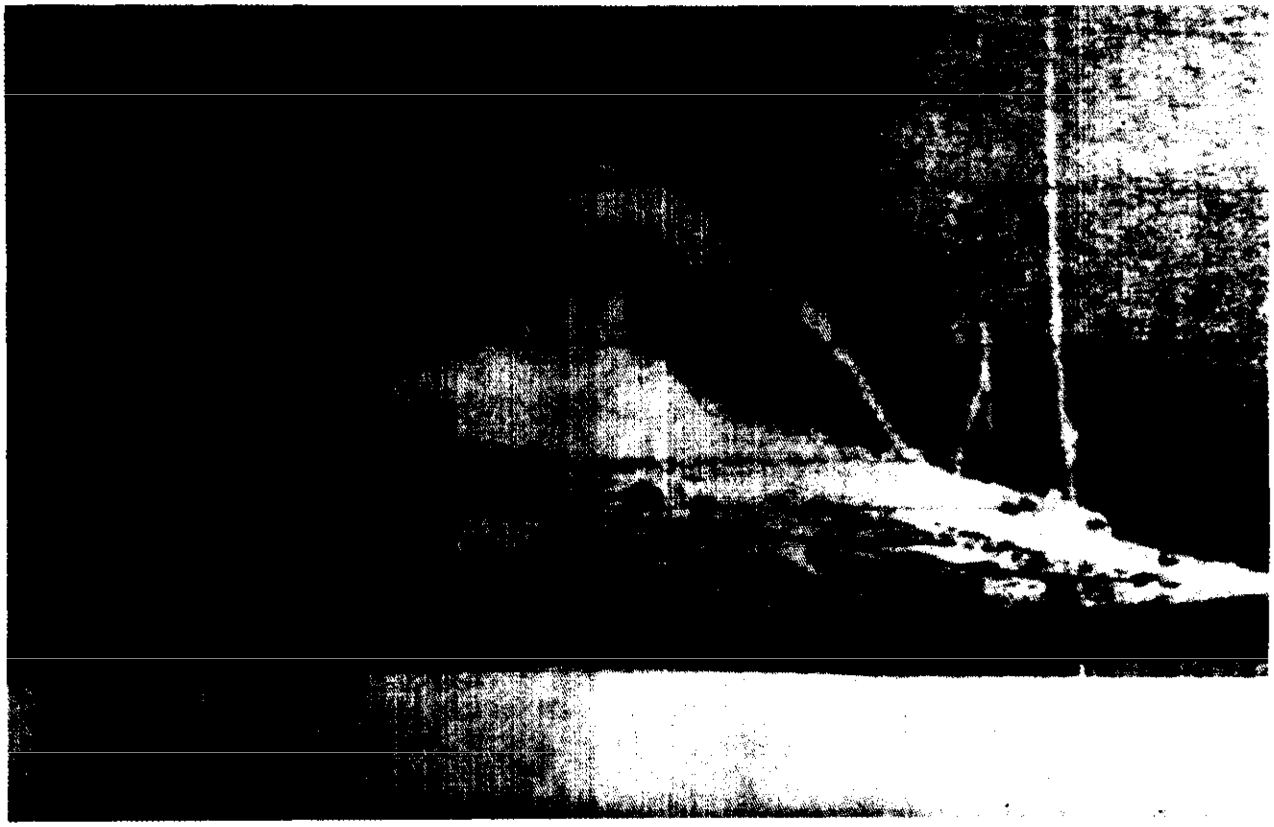


Photo credit: Garry Kozak, Klein Associates

Side-scan sonar of the ***The Atlantic***, a wooden side-wheel U.S. steamship sunk in 1852, in the Canadian waters of Lake Erie. The ship rests nearly upright, 160 feet below the surface. Because it lies in cold, freshwater, it is remarkably well-preserved.

of airborne magnetometry could lead to faster, broader, and more accurate coverage within survey perimeters.

Remote sensing from aircraft and space, when it is refined to penetrate more deeply below the water's surface, could be applied to underwater archaeological site identification and management, as it has been to hydrography.[85]

Remotely operated vehicles have been undergoing rapid change and development, going deeper to bring clearer pictures than ever before of the sea bed.[86] Developed in response to the needs of the military and oil, gas, and minerals exploration companies, they are replacing human divers in a great many underwater tasks. They can remain submerged for weeks to survey huge areas of the oceanfloor. For example, the historic discovery of the wreck *R.M.S. Titanic*[87] in April 1986 was achieved through an unmanned craft, the *Argo,* tethered to a ship by 13,000 feet of cable. Outfitted with television cameras, high-powered lights, and sonar scanners, it revealed new information about an environment that had previously been closed to archaeological research. The *Titanic* was later explored by a manned vehicle, the *Alvin,* and a remotely operated craft, *Jason,* jr. in an attempt to gather visual

[85] J. Barto Arnold, III, "Remote Sensing in Archaeology," *The International Journal of Nautical Archaeology and Underwater Exploration,* 1981.

[86] Craig T. Mullen, Eastport International, Inc., personal communication, 1986.

[87] Robert D. Ballard, "How We Found the *Titanic, National Geographic vol. 168, 1985,* pp. 696-722.

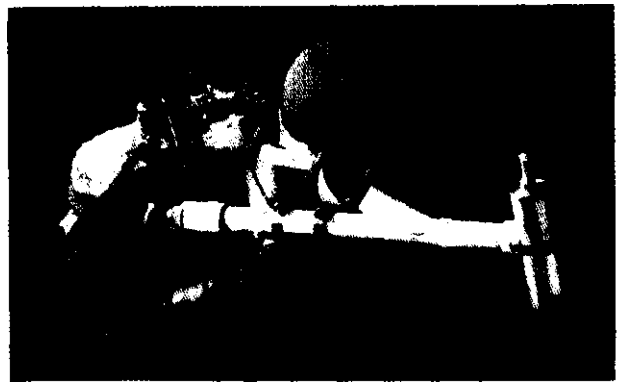
and other data on the wreck's condition .88 The *U.S.S. Monitor* has been surveyed by the Navy's Deep Drone, a highly sophisticated ROV that was also used in the recovery of the remains of the *Challenger* space shuttle.[89]

/formation technologies make a substantial contribution to research and management of maritime and underwater cultural resources. Although the various technologies for archiving, retrieving, and manipulating the many research and historical records related to underwater archaeology and maritime preservation are not unique to these subjects, they are an integral part of the preservation process. Of particular interest to underwater archaeologists and maritime preservationists are automated databases, and the use of optical disks for the storage and retrieval of both visual and textual information. Both technologies require the extensive use of computers to be effective.90

Navigation

Archaeologists can acquire a variety of navigation tools, depending on the nature of their search and desired accuracy. In the coastal waters of the United States, the LORAN-C system maintained by the U.S. Coast Guard enables site relocation within around 10 meters. Microwave positioning systems allow "repeatable fixes" within 3 meters or less. Space-based navigation systems allow positions to be fixed within several meters. 91

A new satellite-based navigation and positioning system known as Starfix, a joint venture between John E. Chance & Associates and Analytical Technology Laboratories, is now available. This system allows accuracies of better than five meters throughout the lower 48 States, including both Atlantic and Pacific coastlines and the Gulf of Mexico, out to around 600 nautical miles. Originated for civilian marine use, primarily by the oil exploration industry in drill rig situating, pipeline laying, and geophysical prospecting, Starfix is the first privately developed satellite positioning system. Starfix offers continuous coverage, 365 days per year in all types of weather.



D H R
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Sonic High Accuracy Ranging and Positioning System (SHARPS)

This system is a new, extremely rapid, and highly accurate means of achieving detailed maps of shipwreck sites. it represents a technological advance over the usual method of charting a submerged area, in which investigators establish a hand-placed grid comprised of plastic lines or

[88] Walter Sullivan, "Manned Sub Descends To View the Titanic, " *New York Times*, July 15, 1986, p. Cl.

[89] Michael D. Lemon ick, "Probing the *Monitor* with a Deep Drone, " *Time*, June 22, 1987, p, 77.

[90] See U.S. Congress, Office of Technology Assessment, OTA-E-319, *Technologies for Prehistoric and Historic Preservation* (Washington, DC: U.S. Government Printing Office, September 1986), ch. 5, for a d iscussion of preservation information tech nologies.

"Charles Mazel, "Technology for Marine Archaeology, " *Oceanus*, vol. 28, No. 1, spring 1985, pp. 87.

Photo credit" Ray A.Williamson

Coffer dam around shipwreck site, Yorktown Archaeological Project.

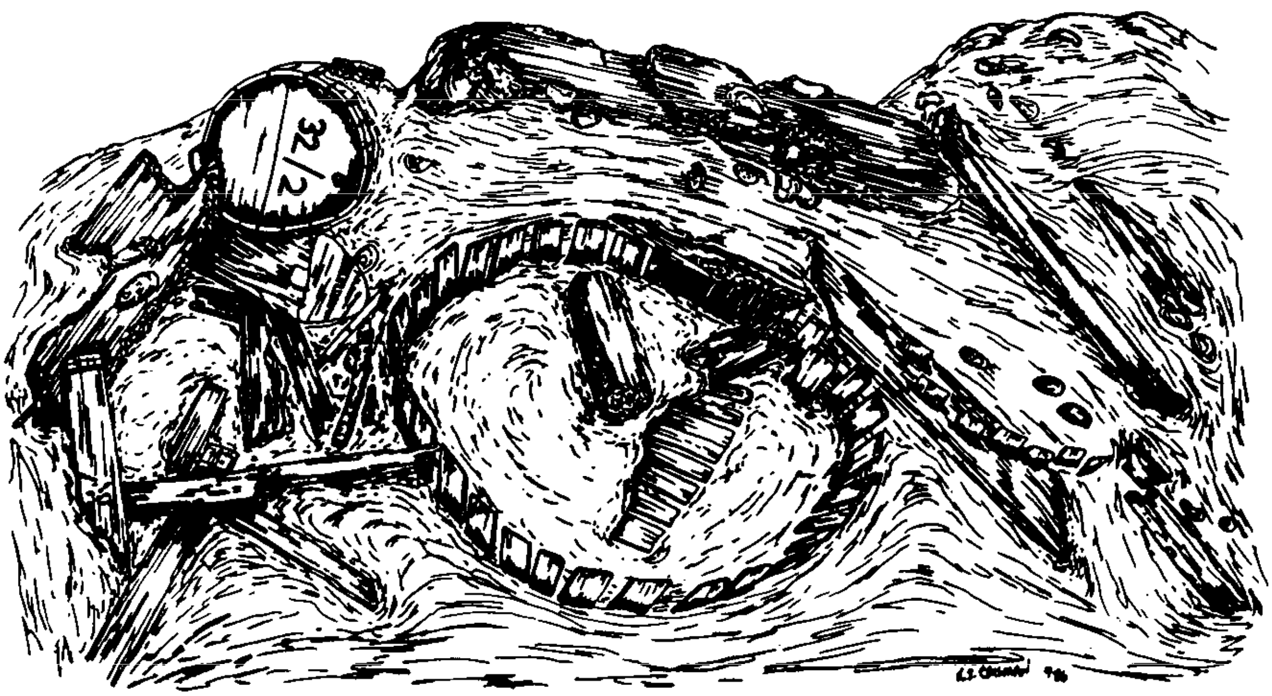

Photo credit: Kevin Crisman, Yorktown Archaeological Project

Yorktown Shipwreck Archaeological Project Shipwreck.

tubing, stretched from a series of posts, over a wreck to enable the hand calculation of thousands of reference points. The usual approach can take months or even years to complete, is labor-intensive, and can be dangerous in deep water because of diver's susceptibility to nitrogen narcosis or "the bends." In the deepest waters, it can be virtually impossible.

SHARPS involves setting up around a site three electronic transmitter-receivers. These transmitter-receivers detect signals from an electronic gun held by a diver at points the diver wishes to measure. When the diver pulls the trigger, the points are recorded by computer on shipboard. This technique allows accuracies to within less than half an inch. The system enables archaeologists to outline vessels and artifacts, create two and three-dimensional maps, and label objects.[92]

Excavation and Documentation

Individuals exploring the sea bottom have a wide array of technologies at their disposal. Deep-water technologies such as tethered and free-roaming ROVS and saturation diving could exert a profound effect on data recovery in underwater archaeology and maritime preservation.

Underwater Excavation Technologies

These techniques range from the extremely simple, such as hand-fanning, to the complex, such as controlled blasting, and include the use of blowers, prop wash deflectors, air hammers, and chisels. Excavation required in dark or "black" water is extremely difficult to carry out, even in relatively calm, shallow water. Specially designed coffer dams such as that developed for the Yorktown Archeological Park in Yorktown, Virginia (box H), are improving the ability of divers to find their way in heavily silted waters. In Yorktown, excavation of an 18th century shipwreck is carried out within a steel enclosure filled with river water that is clarified by commercial filtration units.

SCUBA Diving

As noted earlier in this background paper, archaeologists make extensive use of SCUBA diving equipment and techniques for exploring and excavating sites in shallow waters.

Deep Sea Diving

The use of saturation divers and deep-diving systems to collect samples at depths totally unattainable to conventional divers has been a major technical innovation. Saturation divers are now able to work at extreme depths for prolonged periods. Bottom times are no longer a function of depth, as they are with SCUBA diving, and each dive can last for many hours instead of minutes. Breathing an atmosphere of mixed helium-oxygen, divers can attain depths of over 1,000 feet, although decompression afterward may require several days. Habitats, lockout submersibles, and tethered deep-diving systems deploy saturation divers to their destinations.[93]

Remotely Operated Vehicles (ROVS)

ROVS also have an important role in gathering data, and can be used to collect samples or to photograph or videotape a wreck site. Scorpio, a particular type of new ROV,[94] is now being equipped with remotely controlled manipulators. ROVS are now capable of achieving depths

[92] Recently, a research team completed several experiments in the Chesapeake Bay demonstrating that placing grids and artifacts can be done as much as a thousand times more quickly through the use of a small shipboard computer and electronic mapping gun. Emory Kristoff of the *National Geographic* and associate, Donald Shommette, with over 1,200 reference points, mapped the remains of an 1883 oyster boat located in the shallow waters near the mouth of St. Leonard's Creek in Calvert County, Maryland, in 1 hour. Previous methods would have required about 6 weeks for the same results. The researchers assert that SHARPS can change the field of underwater archaeology, putting all sites within easier reach. This technology is the product of government and private sector cooperation, and was developed with the participation of the U.S. Navy, NOAA, several Maryland State agencies, and the National Geographic Society, See *The Washington Post,* Science Notebook, "Reading Tales of Shipwrecks, " Susan Okie and Philip J. Hilts, Mar. 23, 1987, p. A3.

[93] Otto Orzech, Scripps Institution of oceanography, personal communication, 1986.

[94] Jonathan B. Tucker, "Submersibles Reach New Depths, *High Technology,* February 1986.

Box H.—Applications of Technology on the Yorktown Shipwreck Archaeological Project

The Yorktown Shipwreck Archaeological Project has provided an excellent test site for applications of technology to underwater archaeology. From the intial surveys to the current full-scale excavation, advanced technology has been applied in all phases of the project.

During the period 1976-1979 the project team conducted a series of [illegible] York River using a variety of positioning systems—side-scanning and bottom-[illegible] netometers. These surveys, followed by hands-on inspection by archaeolo[illegible] and mapping of nine shipwrecks from the [illegible] Battle of Yorktown, includi[illegible] HMS *Charon*. Throughout the survey period, investigations were hampered b[illegible] mal visibility in the York River is usually less than 1 foot. Strong currents a[illegible] the difficulty of working in the river.

In order to offset adverse site conditions and to permit more thorough and accurate documentation, funds were obtained for the construction of a steel enclosure, or cofferdam, around the best-preserved of the Yorktown shipwrecks. The cofferdam allows the enclosed water to be filtered and clarified, utilizing a commercial filtration system, thus improving speed, accuracy, and efficiency, and permitting a photographic record of the site to be made. The filtration process increases the visibility inside the protective coffer dam to more than 20 feet.

A pier connecting the cofferdam to the shoreline, just under 500 feet away, permits visitors to observe the work in progress and to learn, from staff interpreters, the importance of maritime preservation and the Yorktown shipwrecks. This is the first such project in the world.

As excavation has proceeded, the staff continues to employ additional advanced technology. Measurements are made using three tape measures, with the resulting data converted to cartesian coordinates by a micro-computer program. Recently, the cofferdam was the site for the first field test of a new sonic positioning system, called SHAR/PS. This system allows a diver to record hundreds of data points, in three dimensions, accurate to a centimeter, on a single dive. [illegible] Enterprises, Inc., a naval architectural firm, is using their computer-aided design (CAD) [illegible], record, and plot hull and artifact remains. Efforts are currently underway to [illegible] allowing site locational data to be fed directly into the CAD system for analysis [illegible] should allow field data to be analyzed and plotted on publication-quality drawings [illegible] recording.

Although visibility in the cofferdam now reaches [illegible] the techniques being developed there, including the SHAR/PS system, will be [illegible] effective in poor-visibility conditions.

SOURCE: John D. Broadwater, Commonwealth of Virginia, Department of Conservation and Historic Resources, 1987.

of up to 13,000 feet and are armed with specialized work packages capable of cleaning oil rig platforms and recovering a vast array of objects.[95]

Conservation

Conservation is "the documentation, analysis, cleaning, and stabilization of an object . . . to protect the artifactual, faunal, and other archaeological material and prevent their reacting adversely with the environment after recovery."[96] Participants in the OTA study agreed that no submerged site should be excavated unless archaeologists can guarantee the proper conservation of the recovered materials. The conservation and protection of underwater cultural resources, like other underwater archaeological procedures, tend to be expensive, require specialized knowledge and facilities, and are complex and time-consuming. Concreted metal, waterlogged wood,

[95] The University of New Hampshire owns possibly the most advanced ROV, EAVE-EAST, autonomous, outfitted with five microprocessors to sense data on altitude, depth, obstacles, and power consumption. Research continues to impart greater dexterity of manipulation and better systems for autonomy.

[96] D. L. Hamilton, "Conservation in Nautical Archaeology," *Underwater Archaeology: The Challenge Before Us,* The Proceedings of the Twelfth Conference on Underwater Archaeology, Gordon P. Watts, Jr., (cd.) (San Marine, CA: Fathom Eight 1981).

and other organic materials such as leather or fabric begin almost instantaneously to deteriorate when exposed to the open air after having been submerged or buried under sediments. They must be immediately reintroduced to water, via holding tanks, or wet-packed for transport to permanent conservation facilities.

In the United States there is a shortage of conservation facilities as well as a dearth of trained, competent conservation personnel to deal with the ever-increasing numbers of cultural materials being recovered from the deep. Some successful conservation must rely, in large measure, on the services of volunteers working u rider supervision. In addition, many projects are directed by non-research-oriented organizations and individuals whose ignorance of appropriate conservation methods ultimately destroys recovered materials.

The following approaches represent the range of conservation treatments available:

- *Full-Scale Conservation.*—This approach calls for the stabilization and continuing care of all waterlogged objects, including ship's hulls. This is the most complex and expensive method, but permits scholars and the public to examine thoroughly historic shipbuilding techniques and any culturally significant contents. This approach necessitates fully staffed conservation facilities with highly controlled environments (humidity, temperature, light, etc.). Conservation processes are time-consuming and tedious and demand a long-term commitment on the part of any agency or institution that assumes the responsibility for applying them.

  For example, the Swedish Government has assumed responsibility for the Wasa for the past 26 years at a cost of over $20 million. The Mary Rose Trust is in the early stages of conservation of the *Mary Rose.* The Mariner's Museum in Newport News, Virginia, has taken on the *Ronson Ship* bow using private funds.[97]

  Even thoroughly stabilized materials remain extremely fragile. Polyethylene glycol is the commonly used wood consolidant and is very costly. However, recent successful experiments using sucrose promise to lower some stabilization costs. Sucrose is very inexpensive and seems highly stable.[98]
- *Combined Conservation and Documentation.*–This approach involves stabilizing all small, portable waterlogged cultural materials and documenting large objects such as the hull; it dramatically reduces conservation costs. Though a significant amount of study is still feasible, some technical knowledge is lost. However, articles must still be housed in properly staffed conservation facilities. For example, the State of Maine conserved the small artifacts recovered from the *Defence*[99] and documented the hull through drawings for only $20,000. The Canadian Government conserved all the small objects from the *San Juan,* molded sections of the hull, and recorded the remaining sections with drawings.[100]
- *Conservation Through Technology.–This* technique, as yet unadopted, would involve recording all small artifacts with holographic techniques and all large artifacts through molding and documentation and require only holding areas and seasonal conservation staffs. The host institution's commitment would be minimal because its staff can easily transport and store all information. A drawback to this controversial approach is that it does not yield any tangible artifacts.
- No *Action.–This* approach leaves sites submerged or buried beneath the seafloor. Deterioration of shipwrecks and other objects is slow and advances in conservation technologies may significantly improve our ability to conserve artifacts taken from a submerged environment. Currently, this approach postpones the detailed acquisition of knowledge

[97]Sheli Smith, Mariner's Museum, Newport News, VA, personal communication, 1986.

[98]See James M. Parent, "The Conservation of Waterlogged Wood Using Sucrose," *Proceedings of the 14th Conference on Underwater Archaeology,* Calvin Cummings (cd.) (San Marino, CA: Fathom Eight, 1986).

[99]After they completed drawings of the vessel, archaeologists reburied her in situ, using sandbags to hold her in place.

[100]Sheli Smith, Mariner's Museum, Newport News, VA, personal communication, 1986.

Photo *credit:* National Trust for Historic Preservation

Technical conserving bottle taken from shipwreck, Maine Maritime Museum, Bath, ME.

about a site. Future technologies might enable the analysis and interpretation of certain buried underwater archaeological components in situ. For example, the Turkish Government has left several shipwrecks at Yassi Ada to be investigated in future years. The State of Maine selected one ship for study after a survey of the entire Revolutionary War Penobscot fleet. The Commonwealth of Virginia reburied the Revolutionary War period Cornwallis Cave wreck in anticipation of more information on the scuttled British fleet.

These alternatives represent different emphases in terms of costs, commitment, and conservation facility readiness and capability. Realistic consideration of the pros and cons inherent in each of the above conservation methods should be explicitly reflected in project research plans. Otherwise, archaeological investigations will result in only unsatisfactory data bases and poorly conserved artifacts.