SHIPWRECKS OFFER CLUES TO ANCIENT CIVILIZATIONS

Brendan Foley hunts for shipwrecks, but he's not searching for gold or jewels. The sunken treasure he pursues comes not in chests, but mostly in curvaceous clay jars called amphorae—the cargo containers of the B.C. world. Holding remnants of goods and foodstuffs produced and traded by ancient civilizations, they are rare and valuable puzzle pieces, strewn and preserved on the seafloor, which scientists could piece together to reconstruct the agriculture, technologies, economies, art, and geopolitics of long-lost eras.

"Ships carry not only economic goods, but the ideas of people," said Foley, researcher at Woods Hole Oceanographic Institution (WHOI). "Even today, something like 85 percent of all goods are carried across water at some point, and that proportion was higher as you go back in time, because there were few roads and no airplanes."

Some proportion of those ships that set sail never made it back to port. So Foley believes the sea is full of shipwrecks too deep to be discovered by human divers. Over the past decade, advances in deep-sea vehicle engineering and DNA sequencing are giving scientists new abilities to search for, survey, and analyze these potentially fruitful archaeological sites, he said. Put another way, technological leaps forward are opening new vistas for scientists to make leaps into the past.

Petros Vezirtis, Hellenic Ministry of Culture

Using modern technology to explore an ancient shipwreck off the Greek isle of Chios, a research team recovered ceramic amphorae. The team included (from left) Theotokis Theodoulou and Dimitris Kourkoumelis from the Hellenic Ministry of Culture, Maria Hansson from Lund University in Sweden, and Brendan Foley from WHOI.

What launched the Bronze Age?

In particular, Foley has set his sights on the Mediterranean Sea during the Bronze Age, a period from about 3,000 to 1,000 B.C. when human civilization swiftly blossomed. The era was named after a technological advance—the development of metallurgy to produce bronze, an alloy of copper and tin, to make more durable goods. But this relatively brief period in the span of human history also spawned advances in cities, art, architecture, agriculture, written language, and long-distance seaborne trade spanning Egypt, Phoenicia, Greece, and island states throughout the Mediterranean Sea, such as Crete, Santorini, and Cyprus.

Ironically, original artifacts made of the very metal that named the era are much more likely to be found under water than on land, Foley said. "All the great bronze artwork in the National Museum in Athens, Greece, was found under water—some of them from shipwrecks; some of them may have been thrown in lakes or just off shore in advance of invasion. Bronze on land isn't preserved, because it's valuable and easily melted down and converted into something else: shields and swords, or later on into cannons or church bells."

"We shouldn't be parked on land and confining our search. There's too much to find out there," he said, pointing on a map to a blue expanse of the Mediterranean.

"This area is a cradle of civilization," he said. "With new techniques and tools for marine archaeology, we can start to look for answers to questions such as: What technological developments enabled the flowering of civilization? What was the nature of contact among ancient peoples? How, when, and where did trade networks first develop? How did trade affect cultural development throughout

Chris Roman, WHOI

In 2005, a deep-diving WHOI autonomous underwater vehicle called *SeaBED* was used to survey and systematically photograph a shipwreck from about 350 B.C. off the isle of Chios.

the Mediterranean world?"

It's hard to categorize Foley, whose research combines archaeology, oceanography, and technology.

"Really, what I want to learn is the roots of our civilization—why we became what we are today," he said.

Piecing together a picture of the past

Foley began working with archaeologists from the Hellenic Ministry of Culture in Greece in 2005, obtaining a list of wrecks that have been reported over the years by fishermen, divers, and other researchers. Many of these shipwrecks, ranging from 700 B.C to 400 A.D., are located near the islands of Chios and Oinousses in the eastern Aegean just off the coast of Turkey.

During that first summer, Foley and a team of Greek archaeologists aboard the research vessel *Aagaeo* dove on only a handful of wrecks. In crystal-clear visibility of up to 200 feet, they used digital cameras encased in special waterproof housings to take dozens of photographs of the wrecks. Then, they used a WHOI autonomous underwater vehicle named *SeaBED* to take additional images.

Back on land, they pieced together the photos to compose detailed photomosaics that offered panoramic perspectives of entire swaths of seafloor. As with most ancient wrecks in that region, the hulls, decks, masts, sails, and most of the other organic material on the ships had been consumed by marine organisms. What remained poking out of seafloor mud was all of the inorganic material—hundreds of empty ceramic amphorae. These had been stacked within the long-gone hulls to carry commodities such as wine, olive oil, olives, nuts, and a type of fish sauce called *garum*.

Various civilizations established their own "factories" to manufacture bulk quantities of amphorae to transport goods, Foley said.

"Different people in different areas and in different times had their own style of ceramic amphorae that you can discern at a glance—they way you can discern a Heinz ketchup bottle from a Coke bottle," Foley said. "So these ceramic vessels are really good indicators of time and place and who was trading with whom."

But that doesn't provide much information about *what* the civilizations were producing or trading.

"Imagine if you were asked to analyze the American economy just by looking at the empty shells of 40-foot shipping containers," Foley said.

Digging deeper with DNA

To find out what had been inside the amphorae, Foley turned to a close friend, Maria Hansson, a molecular biologist at Lund University in Sweden. She pioneered a sampling technique that enables researchers to swab the interior of ostensibly empty amphorae for traces of ancient DNA.

"Even if it looks like everything has been washed off, we can still detect quite a number of things," Hansson explained.

Hansson examined swabs from two amphorae recovered from a wreck off the coast of Chios, which the Greeks had discovered in 2004 and Foley and others examined the following year.

Hansson and Foley reported their findings in a 2007 article in the *Journal of Archaeological Science*. According to DNA data, one of the amphorae held an olive product (probably olive oil), flavored or perhaps preserved with oregano. The other most likely contained wine, because it appeared to contain fragments of DNA from terebinth, a plant that grows on Chios and was used to preserve wine.

Down the road, Foley hopes to apply this technique to other wrecks, combining DNA and other data to reconstruct the movement of crops and commodities across the Mediterranean region.

"If we can get an idea of how food was being preserved and prepared and what sort of value-added products were moving across the Mediterranean between cultures, it would be outstanding," he said. "If you go back to the fundamental questions of how civilization grows

and spreads, maybe a precondition for large populations living in marginal areas like the Greek Isles includes the importation of foodstuffs from other, more fertile spots."

Chris Linder, WHOI

In the future, autonomous underwater vehicles, such this WHOI-developed vehicle called *REMUS*, could be deployed right from shore to search for shipwrecks, avoiding the need to use costly ships.

Where people can't go

But first you have to find amphorae—and that's where autonomous underwater vehicles (AUVs) have the potential to expand the field. Unlike humans, who can't safely dive deeper than about 130 feet (40 meters), AUVs can reach into the depths. They can be programmed to conduct systematic sonar surveys covering many square miles of seafloor per day to search for wrecks.

That significantly ups the odds of finding more wrecks—including many in previously inaccessible deep-sea regions. Once wrecks are located, AUVs can map and survey the sites in the future, they may be able to retrieve artifacts in places where divers cannot go or accomplish tasks more quickly than divers in shallower areas.

"We can get new information about ancient ships traveling long-distance routes, not just day-trippers staying close to shore," Foley said. "We [humans] can never be there ourselves. We need these robotic vehicles to act as intermediaries linking us to these sites.

"Instead of concentrating resources on a single site over many years as has been the practice in underwater archaeology, soon we will be able to survey dozens of sites in a single field season," Foley said. "Eventually AUVs will be deployed from shore, reducing project costs by eliminating the support ship."

Foley hopes to try that experiment, deploying WHOI-developed AUVs called *REMUS* (Remote Environmental Monitoring UnitS) from the Egyptian shoreline.

"The Egyptian Mediterranean coast in particular is probably one of the least-explored coasts in the whole Mediterranean region," said Emad Khalil, director of the Centre for Maritime Archaeology and Underwater Cultural Heritage at Alexandria University. "The use of advanced methods and techniques, as well as cooperation between institutions which are interested in the region, will certainly reveal a lot."

Foley is also teaming with WHOI engineer Dana Yoerger and WHOI geophysicist Jian Lin on a project with the Algerian government to mount a multibeam sonar on an Algerian naval vessel and map the entire Bay of Algiers in the western Mediterranean.

The scientific goals are twofold: to map submerged active seismic faults to assess Algeria's vulnerability to major earthquakes and tsunamis and help the government better prepare for them, and also to seize the opportunity to find shipwrecks and rediscover the country's rich maritime history, which extends at least as far back as the 10th century B.C., Foley said.

Shipwrecks farther afield

Meanwhile, as plans for Mediterranean expeditions continue to unfold, Foley has also pursued an underwater archaeology project in the Stockholm Archipelago in Sweden. There, with the help from archaeologists representing the Swedish National Maritime Museum and the Univeristy of Southampton in England, Foley plans to build a small diver sled, with a thruster, for shallow-water investigations.

The sled will have a Doppler velocity log for relative navigation and a multibeam sonar for precise and accurate mapping of seafloor features. Eventually, Foley hopes to equip the vehicle with a stereo-pair color-camera system and use it as an AUV to create photomosaics of Viking-era shipwrecks.

Many of these ships are much more intact than their counterparts in the Mediterranean, because the low-salinity Baltic Sea lacks zooplankton that eat wood. Many of these wrecks have decks, masts, and bowsprits still standing and barrels full of cargo between the decks.

"It's the sort of vision of a shipwreck that Hollywood directors have in mind—ghost ships sitting on the seafloor," Foley said.

The big challenge in this environment will be visibility. On good days, researchers report visibility of no more than 5 feet—a green-shifted, dark, and gloomy place to try to image a shipwreck.

"With this technology, any shipwreck within diver-depth we can map to a high quality in maybe less than half an hour," Foley said.

If they can prove the concept in the Baltic, they will take the technology back to the balmier Mediterranean.

—Matt Villano

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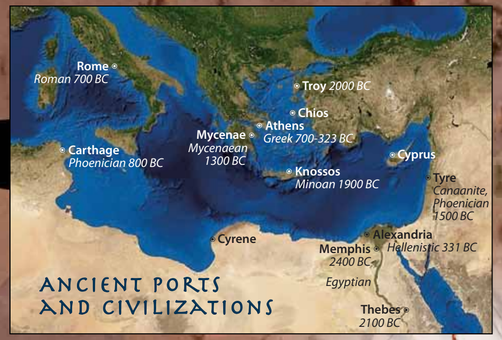
DEEP-SEA ARCHAEOLOGY



The Mediterranean Sea was the interstate highway system of the ancient world. Ships' hulls stuffed with clay jars called amphorae—the cargo containers of the B.C. world—carried goods and foodstuffs produced and traded by early civilizations. Not all ships made it back to ports, however.

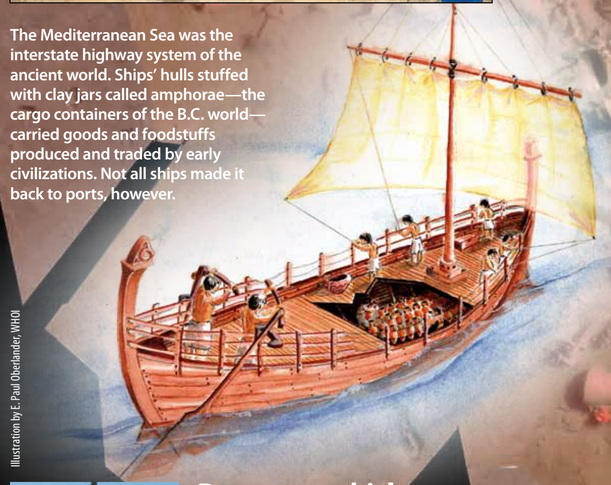


Illustration by E. Paul Oberlander, WHOI

Tom Kleindinst, WHOI

Deep-sea vehicles

New deep-diving robots expand scientists' ability to find ancient shipwrecks. The ships' wooden hulls decompose, but their ceramic amphorae will be preserved, holding clues that scientists can piece together to reconstruct the agriculture, technologies, economics, art, and geopolitics of long-lost eras. This photomosaic of a wreck from about 350 B.C. is composed of 350 individual photos systematically taken by a robotic vehicle called *SeaBED* (left). The wreck was found off the coast of the island of Chios.

Shapes reveal origins

DNA discloses contents

"Different people in different areas and in different times had their own style of ceramic amphorae that you can discern at a glance—the way you can discern a Heinz ketchup bottle from a Coke bottle," said Woods Hole Oceanographic Institution researcher Brendan Foley. These ceramic vessels provide clues to who was trading what with whom and when.

Foley collaborated with Maria Hansson at Lund University in Sweden to sample traces of ancient DNA from inside the amphorae to determine what they held. The 3-foot-tall amphora on the left was made in Chios and contained olive and oregano (probably used as either flavoring or a preservative). The origin of the amphora on the right is still unknown, but its DNA analysis showed that it contained terebinth, a resin from a shrub related to pistachios.

Sponge