8

The Remote Exploration and Archaeological Survey of Four Byzantine Ships in the Black Sea

Cheryl Ward and Rachel Horlings

A pilot project to explore shallow- and deep-water environments in the Black Sea as part of a long-term project developed by the Institute for Exploration (IFE) tested survey methodology and equipment for deep-water archaeological applications. The application of traditional and innovative remote-sensing methods supported standard archaeological approaches to site survey in a relatively hostile marine environment and resulted in the discovery of four shipwrecks that date to the 4th to 6th centuries CE, including one of the best preserved seagoing ships from antiquity, a discovery predicted by Willard Bascom (1976:38). This chapter reviews the maritime survey, describes methodology used to locate four ships in 2000 and data recovered from those sites in 2000 and 2003, presents preliminary conclusions about those vessels, and discusses directions and possible implications of future research.

Background

Collaborative efforts under the overall direction of Robert Ballard brought the Institute for Exploration, the University of Pennsylvania, University of Rhode Island Graduate School of Oceanography, the Massachusetts Institute of Technology, Woods Hole Oceanographic Institute, the Institute of Nautical Archaeology, and Florida State University together for a program of terrestrial and marine survey focused on Sinop, Turkey (see figure 7.8) (Ballard et al. 2001; Ward and Ballard 2004). The Holocene transformation of the glacier-fed Euxine Lake into the Black Sea when it was inundated by salt water from the Mediterranean Sea created a new landscape, including an underwater realm where few organisms could survive. As salt water flowed into the closed basin, it essentially smothered the freshwater below it. Very low rates of internal motion and mixing meant no fresh oxygen reached the deep waters after the influx (Oğuz et al. 1993). At 150 m or deeper, there is insufficient oxygen to support most biological life forms, between 170 and 200 m, a suboxic zone is characterized by low oxygen and low sulfide content, and below 200 m is an anoxic layer with consistently high concentrations of sulfides and low oxygen, which results in conditions that promote preservation of wood and other organic matter (Murray et al. 1989; Codispoti et al. 1991). The speed and intensity of inflow are debated (Aksu et al. 2002; Görür et al. 2001; Ryan et al. 1997; Uchupi and Ross 2000), but evaluation of mollusc shells from a scoop sample collected during the 1999 survey season suggests that the extinction of freshwater molluscs and replacement by saline species took place between 7460 and 6820 BP (uncorrected radiocarbon years), about 7000 years ago (Ballard et al. 2000). In addition to providing convenient harbor facilities today, Sinop played a central role in regional trade from even before Greek colonies were established in the 8th century BCE (Hiebert 2001:16; Doonan 2004). The project's four brief seasons of maritime survey were based there.

In addition to maritime surveys, a multiyear terrestrial survey led by Fredrik Hiebert, Owen Doonan, and Alex Gantos located hundreds of archaeological sites (Doonan 2004). Terrestrial team members recorded all archaeological sites they encountered but focused particularly on identifying the pattern of settlements in the landscape that existed at the time of the flooding of the lake in order to seek similar landscapes along the now-submerged ancient shoreline. They found a number of small, relatively isolated, Neolithic sites on elevated areas that often overlooked watercourses and, on one of Sinop's highest points, a stratified Bronze Age village with extensive trade connections indicated by ceramic remains (Hiebert et al. 1997). Hiebert (2001) and Doonan (2004) believe that these and other sites from the time of Greek colonization through the medieval period (Kassab Tezgör and Tatlican 1998) indicate that the archaeological remains of people who lived near Sinop in the past show a specialized maritime adaptation to a coastal environment. The maritime survey was designed to seek additional evidence of that adaptation. David Mindell directed underwater surveys of Sinop's anchorage, conducting a side-scan sonar survey of waters less than 60 m deep near Sinop harbor in 1998 and returning in 1999 to examine several dozen anomalies through images provided by camera-carrying remotely operated vehicles or ROVs (Mindell et al. 1998). Few anomalies proved to be of archaeological origin, but a late 18th-century CE iron anchor, a large storage jar, and the remains of a 19th-century steamship were identified. Work northeast of Sinop at depths up to 150 m focused on a search for the ancient coastline of the Black Sea (Ballard et al. 2000:614).

In 2000, the team worked 15–30 km west of Sinop, seeking information about the submerged landscape and potential trade routes that might be indicated by the remains of shipwrecks or jettisoned cargo. Historical and archaeological studies on land indicated long-distance exchange dated to at least the mid-5th millennium BCE and that the most intense period of seaborne exchange was between the 2nd and 7th centuries CE in the period of late antiquity (Hiebert et al. 1997; Hiebert 2001; Doonan 2004). In 2000, remote sensing (side-scan) surveys were conducted and targets or anomalies were investigated using ROVs with video and still photograph capabilities.

Four shipwrecks dated to the 4th to 6th centuries CE (Ward and Ballard 2004) and a site originally interpreted as evidence for human habitation in the Neolithic period (Ballard et al. 2001) were located. In 2003 the team returned to four of five sites with an ROV especially designed for deep-water archaeological investigations that require precision documentation and subsurface testing. Project goals set and achieved by the team included demonstrating the ability to conduct standard archaeological survey in deep water and testing the hypothesis that deep-water shipwrecks exist in the Black Sea and are far better preserved than shipwrecks in the upper marine waters. Limits on the data acquired and a lack of processing of some data streams do not permit us to generate full descriptions of the sites but do enable particularistic examination of each ship as well as a discussion of the potential contributions of deep-water archaeology to the study of maritime societies, exchange, ancient ships, and seafaring.

The 2000 Season

In 2000, *Northern Horizon*, a vessel with dynamic positioning capability able to launch and recover the necessary vehicles, served as the research platform (Coleman et al. 2000:661). After preliminary bathymetric data were examined to determine where ancient waterways or hills may have been located, survey paths were laid out by Ballard in search of features such as relic stream beds in the submerged landscape and shipwrecks. Acoustic targets acquired by a DSL-120 phased-array, deep-towed side-scan sonar system (Singh et al. 2000) were investigated using the ROV Little Hercules and optical towsled Argus, both developed by IFE (Coleman et al. 2000:662–4; Coleman 2002). Argus carries lights and cameras, including a 3-chip video camera, an electronic still camera, and a 35-mm color still camera, and moves independently with thrusters controlled from the ship as it locates acoustic targets originally identified by the DSL-120 with a 675-kHz fan-beam scanning sonar mounted directly on the towsled. To limit the effects of ship motion and cable drag on the ROV, Little Hercules is tethered to Argus. Little Herc carries cameras capable of providing extremely high-quality images, obstacle-avoidance sonar, sensors for pressure, depth, and compass heading, and thrusters for lateral and vertical movement. Outstanding visual images permitted preliminary examination of sites, but no measured plans or complete photomosaics were produced and measurements provided here were estimated by comparison to objects of known dimension.

At each site, pilots maneuvered Little Hercules at a sufficient elevation to avoid the site while remaining close enough to investigate artifact and feature details. The archaeologist directing the investigation guided pilots and determined which areas and objects to focus on. Argus hovered above and behind Little Hercules, providing light, recording video and ESC images, and providing a more comprehensive view of the wreck area. No artifacts were recovered in 2000, but sediment and wood samples were collected for analysis and radiocarbon dating at site 82 and site D (Ballard et al. 2001:614, 620). Project staff examined more than 200 acoustic signatures identified in DSL-120 side-scan sonar tracklines, and ROVs subsequently inspected 52 anomalies considered to be candidates for ancient settlement or other archaeological sites.

Five targets met survey objectives (Ward and Ballard 2004:3). Site 82, originally interpreted as a preflood habitation site (Ballard et al. 2001:613), and four ancient shipwreck sites were explored and visually recorded. Sites A, B, and C are at depths of 85 and 95 m, and site D is located in the anoxic layer at 324 m. Sites A, B, and C exhibit the classic mounded deposit of an undisturbed ancient ship carrying a cargo of transport amphora; site D consists of a wooden sailing ship sitting upright on seabed, buried in sediment to deck level (Ballard et al. 2001:619; Ward and Ballard 2004:5–8).

The 2003 Season

In 2003, National Science Foundation and other funding permitted an expanded team of oceanographers, archaeologists, engineers, and a conservator to return to the Black Sea on RV *Knorr* with Argus, and a new ROV named Hercules, built to IFE specifications with tools designed for subsurface testing and survey. Hercules and Argus worked in the same configuration tested by Little Hercules and Argus in 2000, but Hercules' capabilities increased the volume of data acquired and provided enhanced capabilities at depth. After a visit to site 82, now considered to represent a geological rather than an archaeological feature, *Knorr* towed the submerged Hercules and Argus to sites B and C for mapping and sampling work before continuing on to site D. At each site, Hercules conducted side-scan and subbottom acoustic survey and acquired electronic still images, but because these data have not been processed, no precise dimensions or site plans are available at present. The descriptions and analysis that follow draw on video and still images from both seasons and on data from artifacts recovered in 2003.

Sites A, B, and C

Sites A, B, and C, shipwrecks at depths of 85 and 95 m, appear as mounds of exposed transport amphoras. These shipping jars are best known to archaeologists today as containers for bulk shipping and storage of liquids such as wine, garum (fish sauce), and olive oil, although a variety of products were carried (Haldane 1991). When merchants loaded ancient ships with shipping jars (figure 8.1), they stacked jars vertically in interlocking tiers to ensure minimal movement in transit and to allow for maximum stowage in the cargo hold

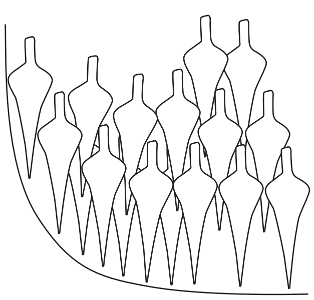

Figure 8.1. A reconstructed lading plan for the late antique shipwrecks relies on patterns of dispersal on the seabed as well as excavations of other ships with transport amphora cargos. (R. Horlings drawing)

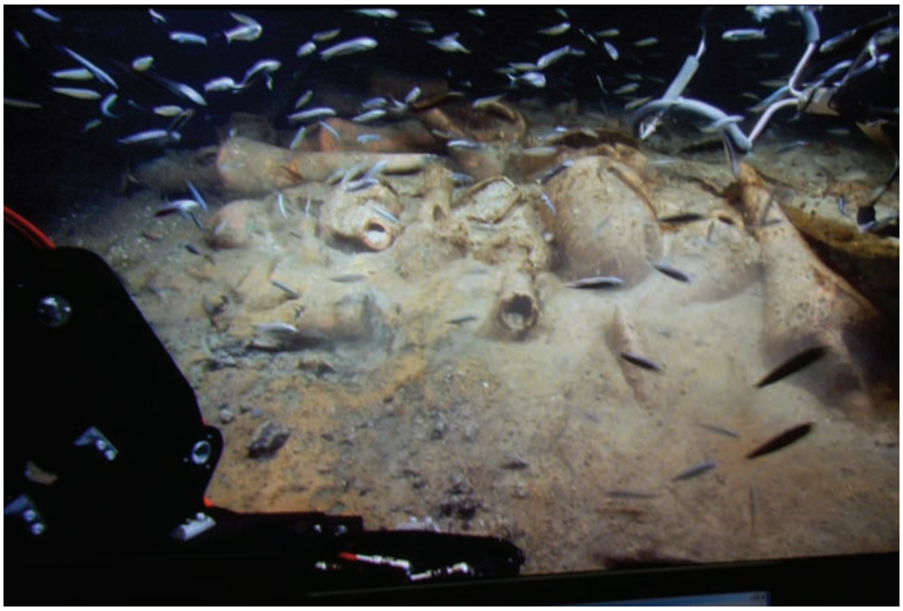

Figure 8.2. Anchovies, algae, sediment and shipping jars were common sights at sites A, B, and C. (Photograph courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

(Casson 1994:104; Gianfrotta et al. 1997:149, 178–85; Grace 1949:175). Most Mediterranean shipwreck sites with shipping jars exhibit similar lading patterns, but many reflect disruption caused by the collapse of the hull, a process often accelerated by the presence of wood-eating organisms such as *Teredo navalis* L., commonly called the shipworm. As the hull disintegrates, jars fall away from the central cargo area and create a sloped mound that traps sediment and often promotes growth of, for example, Poseidon grass. Wood preservation on the surface of most sites is minimal, although portions of the hull buried in near-anaerobic conditions remain. In the Black Sea, similar processes were evident at sites A, B, and C (figure 8.2).

Each site includes timbers and objects identifiable as modern or recent debris deposited since the wrecking of the ships. Such debris is representative of the long cycle of site formation under similar processes operating during the last 15 centuries. Sites A, B, and C resemble Mediterranean shipwreck sites in terms of site formation processes, but sites A and B have considerably more wood protruding from the mound of jars than is usual on Mediterranean shipwreck sites of similar age. Fluctuations in the anoxic water layer usually found below the depth of these sites likely accounts for the presence of the wood today, but the origin of the wood is unknown. We suspect some of the timbers are original and others are more recent deposits, but at present, we lack evidence in the form of scientific dating or technological features to identify any timber visible on any site's surface as belonging to the original ship.

Site descriptions and observations rely on video and still imagery from the 2000 and the 2003 field seasons and on artifacts and samples raised in 2003 (Horlings 2005). Partial photomosaics were generated from electronic still images acquired during site visits, but as yet, no complete mosaic exists for any site and no detailed plans have been created. Instead, Horlings created preliminary site plans for sites A, B, and C using video footage, still images, and

TABLE 8.1.
ESTIMATED DIMENSIONS OF SHIPS A–D AND ESTIMATED SITE AREAS

Shipwreck site	*Length (m)*	*Width (m)*	*Elevation (m)*	*Section area (m^2)*	*Total exposed site area (m^2)*
Site A	18.0	10.0	1.0–1.5		180
Main	13.0–14.5	5.0	1.0–1.5	65.0–73.0	
Small	3.0	3.0	0.5	9.0	
Site B	14.0–16.0	12.0–13.0	2.0		210
Site C (2000)	8.0–8.5	7.5	0.5		64
Section 1	5.0	3.0–3.5	0.5	15.0–18.0	
Section 2	3.0	3.0	0.5	9.0	
Section 3	4.5–5.0	3.0	0.5	14.0–15.0	
Site C (2003)	8.5	7.0	0.5		60
Section 1	4.5	2.0	0.5	9.0	
Section 2	4.0	2.5	0.5	10.0	
Section 3	5.0	3.0–3.5	0.5	15.0–18.0	
Site D	12.0–14.0	3.5–4.0	–		42–56

partial photomosaics of the wreck sites. Because no processed measurements from the sites are available to the archaeologists, we relied on known dimensions of carrot-shaped jars, about 0.88 m long, to estimate approximate dimensions (table 8.1). Relative placement of objects was determined by examining different image sources and angles but does not reflect direct measurements. All dimensions are tentative as no elevations or overall measurements were generated from acquired data and those presented reflect estimates based on video and still images.

Site A

Site A covers approximately 180 m^2 in two areas (figure 8.3). Area 1 is a large, low, oval mound made up of orange, carrot-shaped shipping jars. As no cardinal directions were recorded in 2000 at site A, the ends of area 1 were arbitrarily labeled end 1 and end 2. Area 1 measures approximately 13 to 14.5 m in length, 5 m width, and 1 to 1.5 m in elevation. Area 2, about 3 × 3 m, also consists of carrot-shaped jars and is approximately 4 m from end 2 of area 1. All visible shipping jars on site A are carrot-shaped, and approximately 0.88 m long. Many jars are nearly upright, occur in clusters (figure 8.4), and seem to reflect the original lading pattern. Shipping jars are not distributed uniformly; several areas on site A have few or no jars visible, and other areas have jars concentrated, stacked in several layers, and densely packed. There are no objects on the surface between areas 1 and 2. Clusters of twigs and branches on the site's surface are almost certainly examples of modern debris. Other objects, such as a plastic sack and what may be a wine bottle, also are modern. Accumulation of modern debris is common on shipwrecks of any age. When only visual data are available, it can be difficult to differentiate between objects of modern and ancient origin.

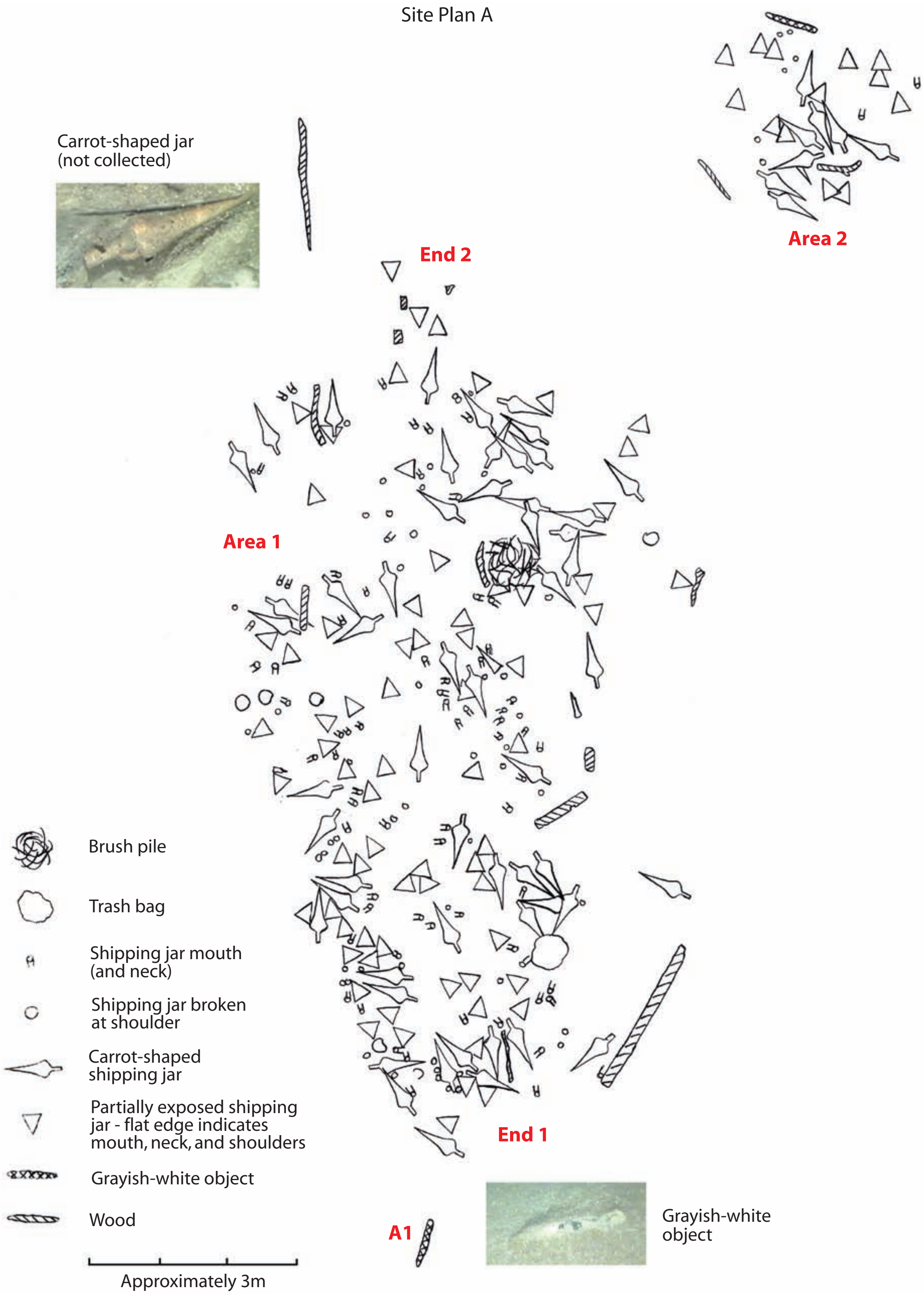

Figure 8.3. Shipwreck A covers about 180 m². (R. Horlings plan)

Figure 8.4. Lading patterns remain visible on the surface of site A. (Photograph courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

Figure 8.5. Light gray objects at sites A (a) and C (b) are probably timbers undergoing bacterial decay. (Photograph courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

Site A also incorporates timbers and some objects with a grayish-white substance on and around them and timbers. Some timbers feature what appears to be notching, shaping, or other purposeful modification, but it cannot be determined from available data whether these timbers were associated with the original ship. One light gray object (figure 8.5a) approximately 0.75 m long, is located at end 1, area 1, about 1 m from the shipping jars. The coloration stands out because it is brighter than the sediment around it, but cause of the color difference is unknown as no samples of this material were obtained. Similar coloration on site C objects photographed in 2000 that are identifiable as timbers in photographs from 2003 suggests the substance may be related to wood decay processes and that these light gray objects are timbers rather than, for example, lead, a gray metal with white corrosion products.

Site B

Site B (figure 8.6) is a 210-m^2, oval mound with a waist measuring about 14–16 m in length with a maximum width of 12 m, rising nearly 2 m above the seafloor. Stacked, carrot-shaped jars like those at site A create internal elevation differences of up to 0.5 m. The surface of site B includes many more broken shipping jars than are visible at sites A and C. The elevation of the mound at B is such that it has trapped twigs, branches, and modern debris and trash, including what appears to be an oil filter. Almost all shipping jars on the surface are carrot-shaped, with slight variations in dimension and shape. The carrot-shaped jars are distributed unevenly across the site, some in concentrations and some scattered individually between stacks of higher and lower elevations, and few concentrations of partially buried jars are visible. None of the shipping jars on the surface is sealed, and many are broken. Several jars contain an unidentified, compact, white substance that has drawn away from the walls (figure 8.7a). Because all the jars containing this substance are located in the center of the site and consequently out of the reach of Hercules' grasping arms, none were recovered for analysis. LRA1 (Late Roman Amphora 1) shipping jars are present on the eastern half of the site (figure 8.7b). Of the five unambiguous examples, four are essentially complete, while the fifth is badly broken. Several mostly buried jars and other large shards in the eastern half of the wreck site may be from LRA1 jars, but are too deeply buried or fragmentary to allow positive identification.

Site B included substantial amounts of wood. Shaped timbers with both rectangular (width somewhat greater than thickness) and plank-like (width at least two times thickness) cross sections are present. At least three timbers, labeled B2, B3, and B4 on the plan in figure 8.5, display intentional modification (figure 8.7c). Other timbers and wood fragments on the surface and protruding from mound sediments may be modified, but data constraints make it difficult to distinguish between intentional modification and erosion. In 2000, we recorded timber B1, approximately 3.7 m long with a plank-like cross section, near the center of site B (figure 8.6). Both ends of the timber were narrower than the body, and the southern end rose at a slight angle. We hoped that we could determine whether this was an intentional modification when we returned, but timber B1 had disappeared by then, serving instead as a reminder of the dynamic forces present on the seafloor and of the difficulty in assigning origins to objects based solely on the interpretation of images.

Site C

Site C was visited briefly in 2000 (Ballard et al. 2001; Ward and Ballard 2004:6) and in 2003. This site is significant because it contributes to understanding the stability of sites in deeper water and demonstrates the capabilities of side-scan sonar in locating archaeological sites. Three clusters of mostly buried, upright shipping jars with a few scattered jars on the surface raise the site only slightly above the seafloor (less than 0.5 m). The only type of shipping jar visible on the site is the carrot-shaped jar, and, as on sites A and B, slight variations between individual examples can be identified. Very few broken jars were visible on the site in either 2000 or 2003. Between September 2000 and August 2003, the

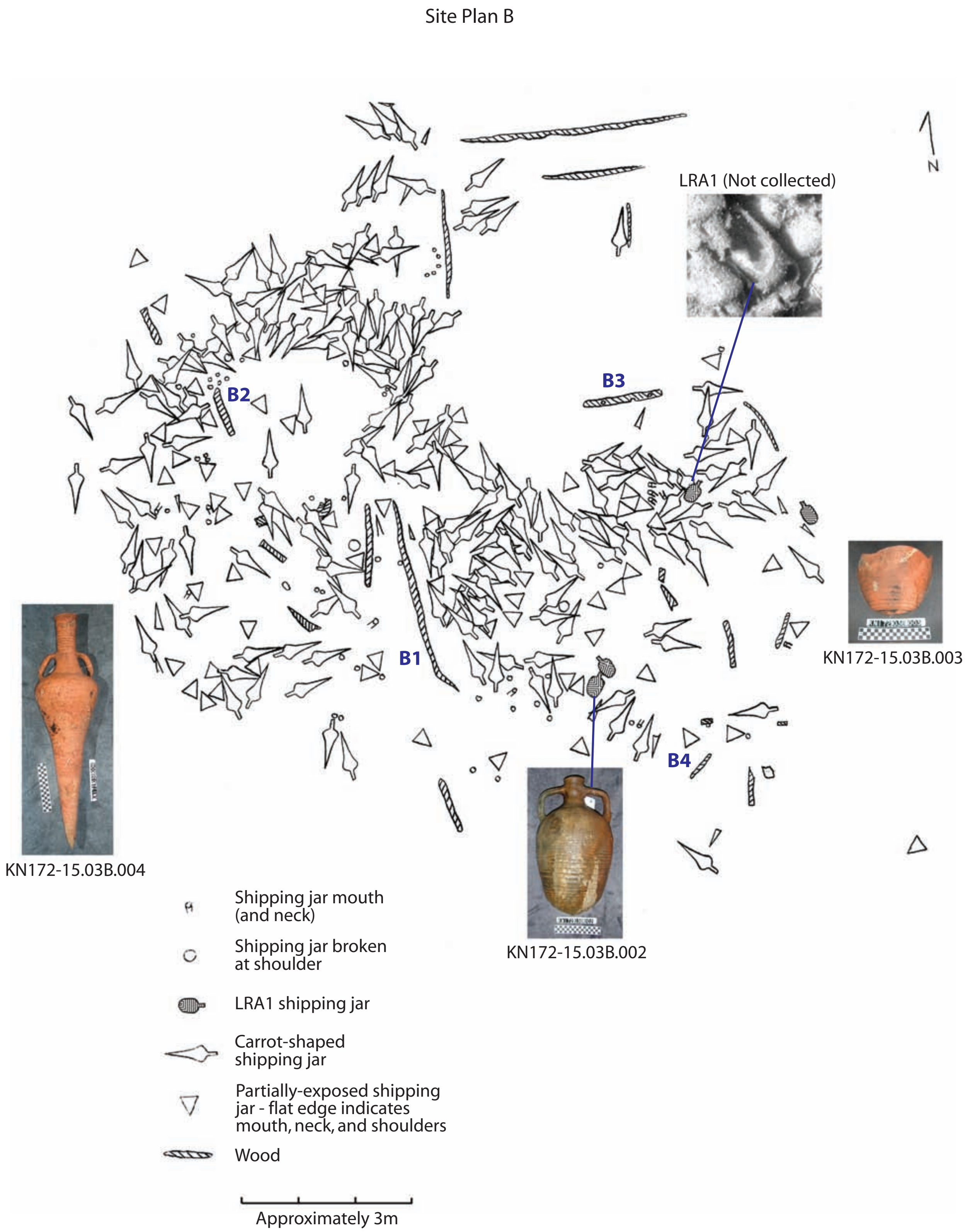

Figure 8.6. The ship at site B is the largest of the four we investigated. (R. Horlings plan)

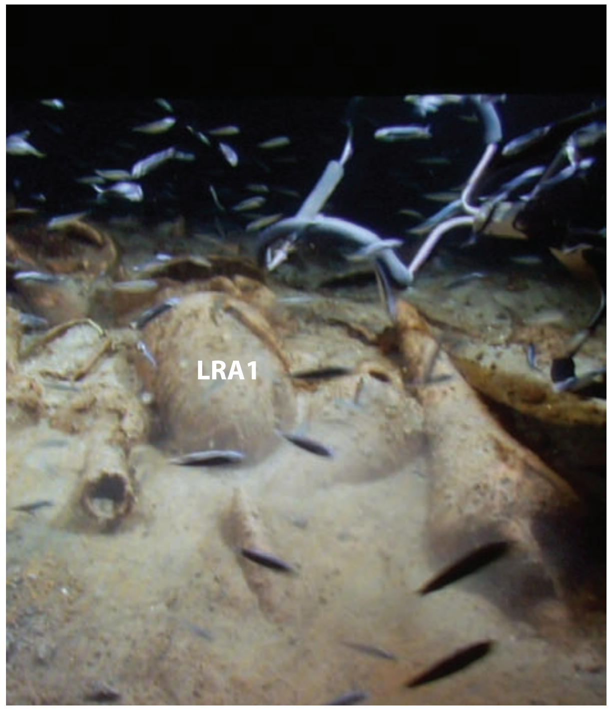

Figure 8.7. (a) Some broken jars at site B contained a compact, white substance that pulled away from the edges of individual jars as it solidified. (b) Site B included both carrot-shaped and LRA1 shipping jars and (c) timbers with notches and other modifications. (Photograph courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

site's appearance changed (figure 8.8). For example, in 2000, 108 jars were visible, but only 89 were exposed in 2003. In 2003, only 60 m^2 of artifacts were visible, while approximately 64 m^2 were exposed in 2000.

As at sites A and B, the slight elevation of the jars above the surface trapped branches, twigs, timbers, and other modern debris. Video images from 2000 indicate that at least one mostly buried timber that may be intentionally modified was associated with shipping jars at site C, but the timber was not exposed in 2003 so no better images are available for studying it. Six light gray objects visible in the 2000 footage and still images (figure 8.5) range from 0.3 to 1.9 m. The light gray coloring appears to be the result of disintegration of the exterior. No gray objects are visible in 2003 images, though two timbers on the wreck site (C1 and C3) are the same sizes and in relatively the same positions as were two of the gray objects in 2000 (C4 and C2). The correlation between the locations of gray objects (2000) and timbers (2003) supports the hypothesis that the gray objects are in fact wooden objects undergoing a chemical or biological reaction to the ambient environment. Too few details are visible on most of the gray objects to allow for identification of original cross sections and shapes, but those that are identifiable appear to be unmodified logs with severely degraded

Site Plan C

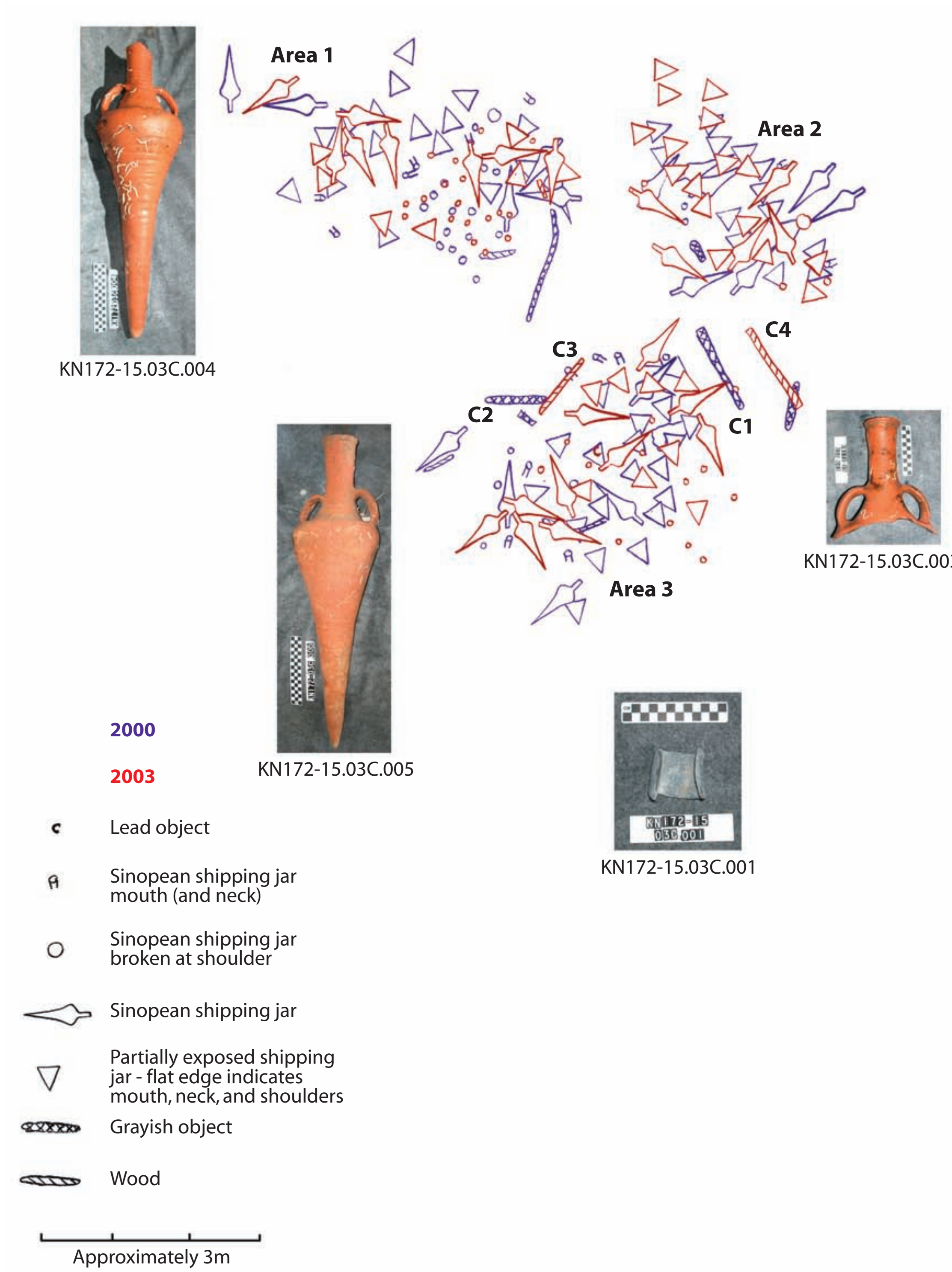

Figure 8.8. A return to site C in 2003 showed significant differences in the number of jars visible on the surface. (R. Horlings plan)

exteriors, suggesting that the same identification is likely for similar objects on other sites, especially site A.

Site D

Site D appeared as a long, slender, and upright feature in acoustic survey data acquired by the DSL-120 at a depth of 324 m about 25 km north of Sinop at the end of the 2000 season. Under the lights of Argus, Little Hercules approached the site as scientists and pilots in the control van saw, for the first time in about 1500 years, a ship's wooden mast standing about 11 m above the seabed (figure 8.9). The ship is buried to its deck in sediment (figure 8.10) and the anoxic environment preserved elements rarely found on shallower shipwreck sites. A fir (*Abies* sp.) wood sample from the rudder support or bollard produced a radiocarbon date of 1610 ± 40 BP (Beta-147532) calibrated to 410–520 CE, and the recovery in 2003 of three shipping jars of a type produced locally in Sinop during the 5th and 6th centuries confirms the ship's antiquity. Ship D may be the best preserved ancient shipwreck yet discovered. Visual survey in 2000 provided a record of the site's appearance used to generate preliminary

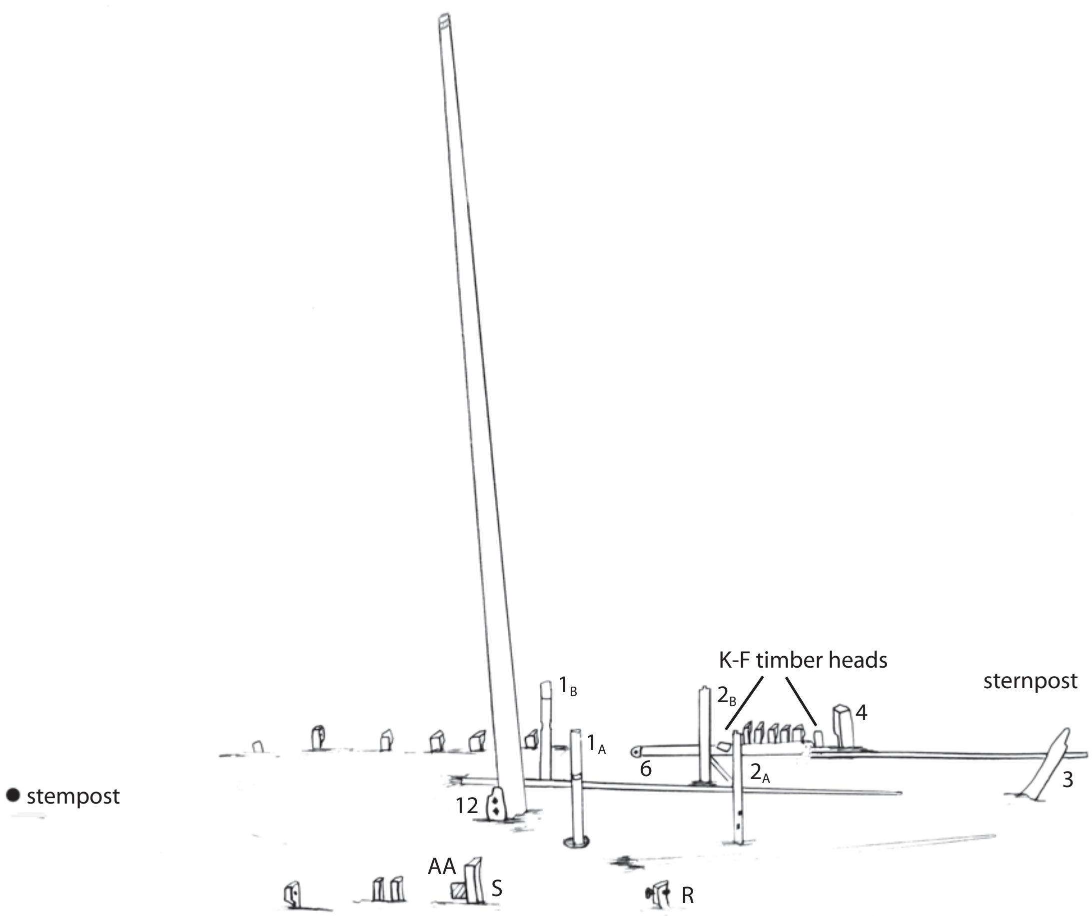

Figure 8.9. Sketch plan of ship at site D. (C. Ward plan)

descriptions of its features and preservation (Ward and Ballard 2004; Ballard et al. 2001). Preliminary analysis of data from 2000 determined the orientation of the hull and identified the vessel's sternpost, a starboard rudder support or bollard, 18 top timbers with holes for pins and one pin, spars, a beam at midships, the mast and its partner, two pairs of stanchions, and a handful of treenails in an area 12–14 m long and about 4 m wide (Ward and Ballard 2004:6–11).

In 2003, survey goals included using Hercules and Argus to acquire sufficient data to generate an accurate site plan, test subbottom profiling and acoustic survey methodology, conduct subsurface testing to locate and examine the ends of the vessel, recover diagnostic artifacts and samples to assist in identifying cargo and hull components, and investigate ship structure. Because time on site was limited, not all goals were achieved, but we did gain substantial new information about the ship at site D. Limited postprocessing of data from acoustic and subbottom survey restricts analysis; although two laser points 10 cm apart were part of the Hercules tool set and provided rough estimates of dimensions, no accurate overall or feature-specific dimensions are currently available.

We arrived at site D mid-afternoon on 3 August and departed at sunrise 6 August 2003. The site looked much as it did in 2000, with the addition of a 12-oz, white and red beverage can. Navigation points were established and provided rough estimates of distances. Before approaching the ship closely, Hercules pilots settled the ROV on the seabed and deployed a suction dredge powered by a hydraulic pump. Two separate nozzles permitted a work routine to be established. The more flexible Kraft Predator arm grasped one nozzle and began to pull it away from the ROV body while suction generated by the other nozzle moved

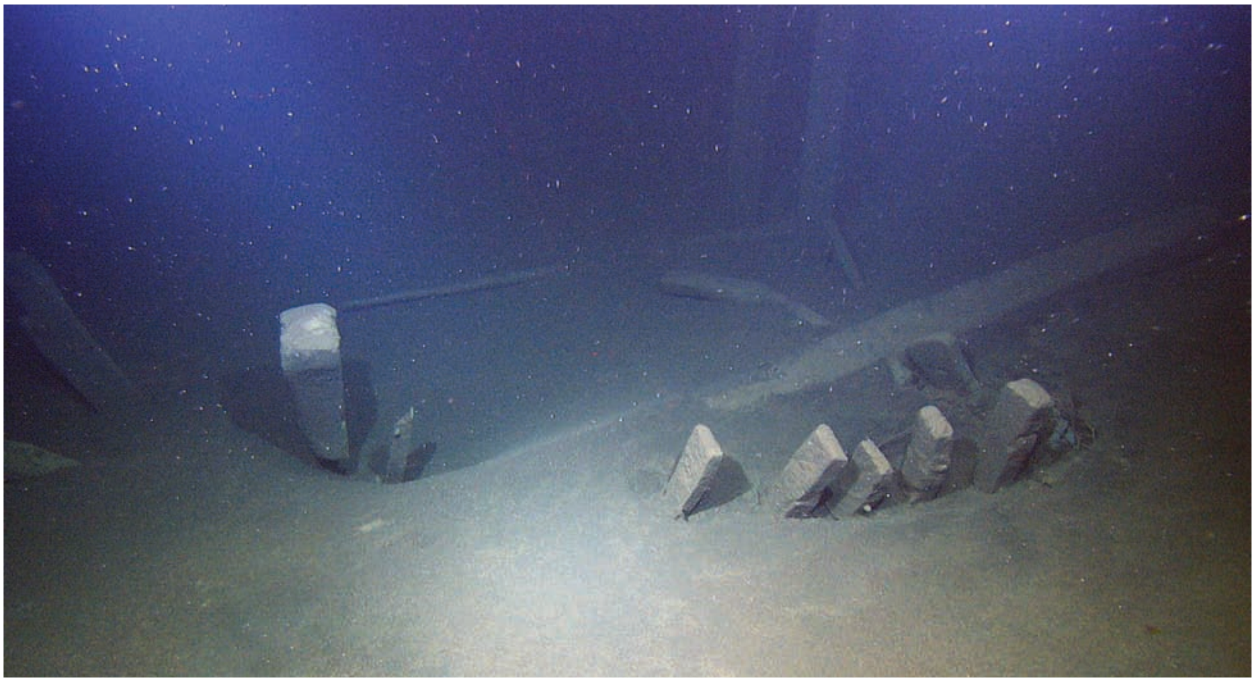

Figure 8.10. A group of six top timbers (F–K) includes one that seems to be out of alignment, perhaps because the heavy spar fell on it. (Photographs courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

sediment in the water column out of the work area, through and behind Hercules, permitting a constant view of the site while the ROV was stationary. Positioning the vehicle so sea currents moved sediment it expelled away from the site was the primary consideration in approaching the ship's starboard side at midships, since each time the vehicle moved, clouds of sediment rose into the water column and required about 30 min to clear before work could again begin.

After exposing some hull planking between two top timbers there, we moved the ROV to the stern where it cleaned the sternpost and removed another 0.80 m of sediment around its base. Although we exposed a total length of about 1.5 m in an area about 0.50 m in diameter, no other timbers were visible. The starboard edge of the sternpost's inner face is broken off, and a large crack is visible lower on the post (figure 8.11a)**.** The scarf and tenon in the upper scarf table of the exposed sternpost and holes for metal fasteners (figure 8.11b) suggest other timbers originally were attached to it. Time constraints prevented the examination of other components (rudder support, top timbers, spars, stanchions) in the stern, and we instead moved to the port side slightly forward of midships.

In 2000, the only artifact other than the ship itself was photographed here, a ceramic jar with one handle visible just forward of a large beam that is immediately before the mast. The lack of hull planking on outboard surfaces of the beam and a nearby top timber was a puzzle in 2000 and remained so in 2003 as no planking was encountered even after excavating to a depth of about 1 m below the beam's lower surface. The beam, once swept clean, proved to be about 0.25 x 0.15 m and was covered with adze marks, emphasized by the swelling of waterlogged tissues, and more visible today than when the ship sailed. The top timber immediately aft of the beam was coated with pitch. Below the beam, Hercules excavated the first 0.5 m of sediment with its alternating dark and light gray layers of soft sediments, and below that, more compacted uniformly lighter gray sediment that incorporated leaves and twigs, exposing pale shipping jars with dark rims of shiny pine pitch.[1] We exposed seven small transport amphoras in an area approximately 2 m long, 1.5 m wide, and 1 m deep. They lay as the ship's crew had arranged them, on their sides and both aligned with the hull's long axis and parallel to it. None of the jars were sealed when found, and no trace of stoppers remained in the three jars we raised to the surface. No hull components were exposed in the subsurface test of the cargo hold, and no deck components were identified.

Exploration of the bow and long sediment ridges that Ward had interpreted as possible spars from the 2000 images followed. We set Hercules down in alignment with the mast and sternpost at a point just beyond the proposed limits of the bow and began excavating one of the more prominent ridges. It proved to be sediment rather than a spar, and no spars or deck components were encountered in this area. Nearby, at a depth of about 1 m, we reached the stempost, about 0.12 × 0.30 m, and visually recorded its scarf and details such as a tenon in the table and a finely bevelled edge on its inner face (figure 8.12). Like the sternpost, the stempost now lacks the timber that once extended its curvature above deck level. No other timbers or fastenings were visible.

In the few hours that remained, we returned to the starboard midships area to direct Hercules in the exposure of the only hull planking identified (figure 8.13). We excavated inside and outside the planking and identified a mortise-

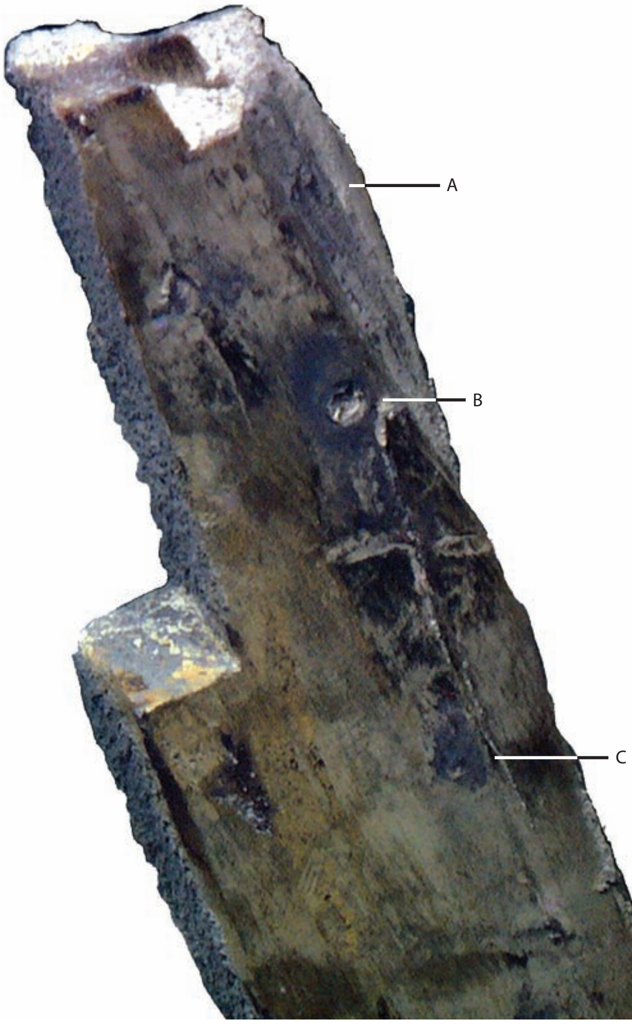

Figure 8.11. The sternpost (a) was excavated to a depth of about 1.2 m; (b) black stains surround holes that probably held iron nails. (Photographs courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

Figure 8.12. The stempost was buried deeply in the sediments. (Photograph courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

Figure 8.13. Our final test area on the ship confirmed that it was at least partially built using mortise-and-tenon joinery similar to Mediterranean ships. Two top timbers, splayed in opposite directions, are about 1.5 m apart. (Photograph courtesy Institute for Exploration, Mystic, CT/Institute for Archaeological Oceanography, URI/GSO)

and-tenon fastening in its upper edge. As in other "test pits," it was clear that significant parts of the hull were missing. Whatever had been attached above this line of planking, and even to this particular plank's after end, was absent. An oak plank[2] fragment recovered by Hercules is coated with pine pitch more degraded than that remaining in the shipping jars. It incorporates part of a mortise-and-tenon fastening.

Artifact Assemblage

All recovered artifacts are curated by the Sinop Museum. No artifacts were collected from site A in 2000, and the team did not return to site A in the summer of 2003. Sampling at site B included artifact recovery and a scoop sample of sediments from the southern edge of the site. Collected artifacts (figure 8.6) include part of a broken, pitch-lined LRA1 shipping jar (KN172-15.03B.003), a complete carrot-shaped shipping jar (KN172-15.03B.004), and a complete LRA1 jar (KN172-15.03B.002). The jar interiors were lined with pitch; preliminary palynological analysis identified high concentrations of pine pollen in pitch samples. None of these shipping jars bears any sort of stamp or maker's mark. Sediment sample KN172-15.03B.005 included *Abies* sp. (fir) and *Pinus* sp. (pine) wood fragments and hardwood twigs.

Artifacts recovered from site C (figure 8.8) included three carrot-shaped shipping jars, one complete (KN172-15.03C.005), one with a broken mouth and toe (KN172-15.03C.004), and the upper portion of a third jar (KN172-15.03C.003). All were coated with pine pitch on the interior. Sediment sample 03C.002 contained *Populus* sp. (poplar) and *Salix* sp. (willow) wood fragments. An unidentified lead object (KN172-15.03C.001) is approximately 0.5 cm thick and 5.5 cm wide. Formed into an incomplete oval 6 cm long, the object appears to have been made of two layers of lead hammered together. Some scratches are visible on its surface, and impressions in the lead appear to have been made by metal tools, though no diagnostic features are visible.

All of the shipping jars at sites A and C, and most of those at site B, are of a type commonly known as "carrot-shaped" (Kassab Tezgör 1999:119; Kassab Tezgör and Dereli 2001). In antiquity, a pottery near Sinop manufactured shipping jars of several types, including a carrot-shaped form in reddish-orange fabric with quartz and pyroxene inclusions (Garlan 1998:31; Kassab Tezgör 1998:447; Kassab Tezgör and Tatlican 1998:441). Similar jars may have been made elsewhere, but it is likely that the jars at A, B, and C were made near Sinop as each of the recovered examples has diagnostic pyroxene inclusions. According to recent studies of Black Sea transport amphoras, carrot-shaped Sinopean shipping jars were most popular in the 4th and early 5th centuries CE (Kassab Tezgör 1996:331, 348; Kassab Tezgör and Tatlican 1998:425). Although the shipping jars recovered in 2003 are similar to those from Demirci, their proportions are not identical. Kassab Tezgör and Dereli (2001:223, see figure 4.13) illustrate seven Demirci types (A–G), of which the closest parallels are types C and D, both with diameters of 0.28 m and respective lengths of 0.80 and 0.94 m. The jars in our sample are approximately 0.88 m long and have a maximum diameter of 0.25 m. Capacity, measured by filling a wet jar to the base of the neck, ranged from 5.7 to 6.3 liters, and the jars weigh between 5.4 and 6.24 kg.

Site B includes a few Late Roman Amphora 1 shipping jars, similar to those found on the Yassıada 7th-century ship in Turkey (Bass and van Doorninck 1982:155–60; van Alfen 1996:191) and elsewhere in the eastern Mediterranean and beyond. There are many variations of the LRA1 (van Alfen 1996:191) and its origins, though uncertain, likely include southwestern Asia Minor and the Antioch region of Northern Syria (Peacock and Williams 1986:186). Production of LRA1 jars dates from the 4th to the 7th century CE (van Alfen 1996:191). Although only five LRA1 jars are visible on the surface at site B, at least two forms are present. KN172-15.03B.002, recovered from midships, is slightly wider at the shoulder than at the base, and of a type dated by Peacock and Williams (1986:187) to the later 5th and early 6th centuries. Zemer (1978:76) dates a similar jar to the 6th to early 7th centuries, a date also assigned to the type by van Doorninck in his study of the Yassıada assemblage (c. 625 CE). A second LRA1 variation photographed but not collected at site B is slightly smaller with straighter sides and may represent van Alfen's type VI (1996:197–198).

At site D (see figure 4.13), we collected three shipping jars of the *patê claire,* Demirci kiln type identified by Kassab Tezgör and Touma (2001). Dated to the end of the 4th through 6th centuries CE, they likely were made in or near Sinop. Demirci-type shipping jars from site D have the characteristic yellowish-green clay color with pyroxene inclusions linked to the Dermirci kiln mentioned earlier (figure 8.14a). Their overall length was inconsistent (0.515, 0.55, and 0.57 m), as was maximum diameter (0.188, 0.218, and 0.205 m). The neck of each recovered jar also happened to be decorated by different means (smooth, horizontal finger ridges, and spiraling ridges). It is typical for this type for the mouth to be poorly finished, as each jar was lined with gleaming pine pitch that extended about a centimeter beyond the rim, forming a smooth edge (figure 8.14b). Kassab Tezgör and Touma (2001:109) note a Demirci-type shipping jar at Dibsi Faraj in north Syria with spiraling ridges on the neck, and several other examples are known from that site and from Ras Ibn Hani, near Ugarit. In 1997, the remains of a small boat or dispersed shipwreck in shallow water at Karakum on Böz Tepe yielded 12 similar jars (Kassab Tezgör et al. 1998) but little else.[3]

In addition to transport amphoras and the lead object, we collected a number of organic samples. A scoop sample from midships at site B produced large numbers of insects and insect frass, fig seeds, and a few weed seeds. In addition to the sample of fir from the rudder support, a second wood fragment, identified as *Quercus* sp. (white oak group), was acquired in 2000 but its original location on the ship is not known. Identification of a 2003 plank sample as oak and pine, fir, and poplar or willow twigs and wood fragments caught in the suction device provides a range of woods local to the Black Sea and harvested there from ancient times. Oak leaves encountered in the sediment around shipping jars also were trapped in the suction device. The leaves may or may not be part of the ship's original contents; a plastic bottle and aluminum can also are present on the surface of site D, reminding us of the continual processes of deposition and movement. Preliminary palynological analysis of sediment samples from the jars reflects the forested environment and, for those jars lined with pitch, indicates a

Figure 8.14. (a) Demirci-type jars on ship D gleamed with pine pitch applied some 1500 years ago, both over the lip and inside (b). (Photographs courtesy Dennis Piechota)

pine origin but does not provide clues to jar contents. Macrobotanical analysis of jar contents likewise is inconclusive, but scheduled evaluation of sediment samples for tannins and lipids may be more informative.

Discussion

The identification of three sites at depths of 85–95 m permitted us to examine shipwrecks that resemble Mediterranean sites in many ways but have some distinct differences. Each of the sites is better preserved than most sites of comparable age in the Mediterranean and includes more substantial timbers on and near the surface than is usual in sites with comparable exposure in the Mediterranean Sea. The shipwrecks have not been disturbed by divers, mooring activities, or fishing, and provided opportunities to test remote sensing equipment and survey procedures. Visiting the sites twice also permits comparison of site features. Large and small timbers are in different locations or missing entirely on sites B and C, and the area and number of exposed artifacts at site C was 8% smaller on the second visit. Site C is subject to the most dynamic surface environment, although it is the most deeply buried site. It is likely to be the best preserved of the shallower shipwrecks. Uniformity of carrot-shaped transport amphora styles suggests that the ships sank at about the same time. Exactly when that was is more problematic as kiln studies suggest that this shape was the predominant type during the 4th and 5th centuries, but LRA1 jars that probably date to the late 6th century are present on site B.

Ceramic styles and a radiocarbon date suggest that ship D sank in the late 5th or 6th century. The 2003 visit provided new data about the ship as well as artifacts from its final lading. The ship seems to be more deeply buried at the bow, which makes it impossible to determine whether the mast is canted forward, as seems possible from images acquired in 2000. In 2000, Ward specified the orientation of the ship on the basis of two pairs of stanchions whose spacing and height reflected images of a 3rd-century mosaic representation from Tunis (Basch 1987:figs. 1105, 1109, 1110) and a 2nd-century ship on Trajan's column and in mosaics at Ostia (Ward and Ballard 2004:9, fig. 10). In addition to stanchions aft of the mast in these images, a stanchion, possibly one of a pair, is shown aft of the mast on a ship in an unusual 5th- or 6th-century mosaic at Kelenderis, Turkey[4] (Zoroğlu 1994:31–2; Friedman 2003:62–73).

The Kelenderis ship is depicted arriving at a harbor, towing behind it two ship's boats on lines attached to sturdy posts beside each quarter rudder. The sternpost protrudes only a little above the highest line of planking, and the stem is higher. A stay runs forward from the top of the mast to the bow, and a second line may represent the halyard tackle, a backstay, or the port shroud. Although the mosaic is damaged at this point, it is possible that the tackle is attached at a point on the vessel's centerline, as is the case for lateen-rigged modern dhows (Facey 1979:164, for example). The mast is lashed to a mast partner and, at a slight distance aft, to a pair of stanchions. It does not appear to be canted.

The quadrilateral sail is spread on a yard portrayed as longer than the ship's hull, and a line of reef points at an angle to the sail's foot dangles in the wind.

A low structure centered on the mast supports what seems to be the furled foot of the sail or a spare sail or shade furled on a spar. A problem in defining the feature is that the bundle is portrayed as being on the port side of the mast, like the standing rigging, and between the backstay and the mast, an impossible position for the foot of the sail. The sail lacks brailing lines but the artist has carefully shown a line of reef points that is at an angle to the yard, a common characteristic of lateen sails and significantly different from the checkerboard-patterned sails with lines of brails prominently shown in many slightly earlier representations (Basch 1987:462, fig. 1030, for example). Although the sail on the small sailing boat is more obviously quadrilateral as Friedman (2003) has observed, in my opinion, the angle of the line of reef points on the large ship's sail and the similar portrayal of the line of reef points on the small boat may indicate an effort to portray a settee or Arabic lateen sail, particularly if the line in the stern is understood as a halyard tackle, points emphasized by Pomey (2006) and Roberts (2006).

Points of similarity between the Kelenderis mosaic ship and ship D include the presence of a mast partner lashed to the mast and to a stanchion immediately behind the mast, an arrangement that would be facilitated by the stepped face of ship D's mast partner and the position and shape of notches in the forward pair of stanchions (Ward and Ballard 2004:10, fig. 12a, b). The mast on ship D has a squared cavity at its top with a remnant of line or of a feature analogous to a mast band intended to support a top. This band is on ship D in the same position as indicated by two white lines on the Kelenderis ship that intersect with the lines and yard and are just below a curved element at the top of the mast. Friedman (2003:65) has suggested the Kelenderis feature is a parrel; the feature on ship D does not display the most important characteristic of a parrel because it is in a fixed rather than sliding position. The structure around the mosaic ship's mast may be the open deck structure or yard cradle proposed in Ward and Ballard (2004:11). A major difference is that ship D at 12–14 m in length was likely much smaller than the Kelenderis vessel, whose size is implied by its two ship's boats.

A mosaic from a Roman house on the Capitoline (Basch 1987:462, fig. 1030) illustrates another prominent feature of ship D. The ship's deck and bulwark are shown with unusual clarity. Top timbers alternate with darker panels and are linked by a cap-rail; they also support a line of planking just at or slightly above deck level. On ship D, some of the top timbers that once outlined the deck remain. About 0.25 m below the heads, treenails about 0.03 m in diameter protrude about 0.025 m outboard of the top timber, suggesting they once fastened the top timbers to planking. There are no traces of panels or cap-rails on ship D, but it is easy to imagine a similar deck enclosure.

Other fastenings on ship D include slightly larger treenail heads visible on each side of the mast partner. These treenails seem to pass through the partner transversely; unfortunately, no high-definition images were acquired in 2003 so responsible speculation about their purpose is limited. Examining this timber from below deck would be illuminating, as its configuration is difficult to explain using the images available. Although the only mast to be published from near this time period has no features that would account for treenails in a mast partner (Riccardi 2002), the mere presence of the mast after some 1500 years may indicate an unexpected method of securing it within the hull. Certainly the ~0.25-m beam before the mast is a partner beam that was locked into the side of the hull, utilizing a notch cut into its end and a second notch cut into the outer face of the top timber just aft of the partner beam.

Unfortunately, the planking, and many other timbers, that could tell us much about precisely how this ship was assembled are missing. A few clues were noted. In addition to mortise-and-tenon joinery used in the stempost and sternpost, the uppermost preserved strake included mortise-and-tenon fastenings, probably unpegged like those in the 7th-century Yassıada ship (van Doorninck 1982). In the sternpost (figure 8.13b), holes surrounded by black stains testify to metal nails, probably iron, but no other timbers are present. No nails were visible in the stempost, but far less of it was exposed as it is more deeply buried than the stern.

It is difficult to imagine what forces would rip planking from the treenails in the top timbers without leaving a trace behind. The force required to remove the sample we acquired was significant, and it had no treenails. It is easier to imagine nails dissolving in the corrosive environment of the deep Black Sea, allowing timbers to loosen and over time drift away, but the absence of so many hull components suggest that the ship suffered greatly in wrecking, upon striking the bottom, or over time. Perhaps the missing planks took the missing top timbers with them when they fell away from the ship. The neatly stacked shipping jars testify to a long period of hull stability even though we found no planking in the area. Wherever we did encounter wood, it was resilient and firmly attached to the hull, so we remain perplexed about the current condition of the ship.

Conclusions

The four shipwrecks identified by the Black Sea project constitute a compact sample when viewed from geographic, economic, and chronological perspectives. The vessels all date to the early Byzantine period (4th–7th centuries CE), and all are slightly north and west of Sinop. Ship D is perhaps one of the best preserved shipwrecks from antiquity, and, if excavated, would provide vital and unique information about the operation of ships and the lives of those who sailed upon them because of the extraordinary preservation of organic materials in the deep Black Sea.

The proximity of ships A, B, and C suggests a pattern of loss, perhaps related to microenvironmental weather conditions associated with the Sinop peninsula, but variations in the shipping jars indicate that we are looking at multiple events, not a single sinking in a storm. Although we cannot predict the intended destination of any of these ships, they each took on cargo carried in transport amphora manufactured in Sinop, and it likely was their last port of call. Did these ships sink just hours out from the town on the route west to Byzantium? Or were they caught in bad weather between picking up a cargo at a vineyard and returning to Sinop or heading out to sea for the Crimea? Our survey cannot provide these answers, but it has demonstrated the utility of side-scan sonar in searching for dispersed targets on a smooth bottom, including one almost entirely buried and one marked only by its mast.

Notes

1. Although the pitch is mixed with other materials, retains its smooth and shiny surface, and seems to be of a wax-like consistency, palynological examination by Dawn Marshall at Texas A&M University indicates that it is a pine product and not a wax.

2. We thank Robert Blanchette, University of Wisconsin at Madison, for his identification of wood from the Black Sea shipwrecks.

3. Three olive stones in the jars, and a lack of pitch lining, prompted the suggestion that the jars carried olive oil or olives (Kassab Tezgör et al. 1998: 441), but without examining the jar walls for lipids, it is not possible to determine if that was the case. Small numbers of olive stones are frequently found dispersed throughout shipwrecks as well as in sediments near shore.

4. I thank Zaraza Friedman for calling this image to my attention.

References

Aksu, A.E., R. N. Hiscott, P. J. Mudie, A. Rochon, M. A. Kaminski, T. Abrajano, and D. Yaşar (2002). Persistent Holocene outflow from the Black Sea to the eastern Mediterranean contradicts Noah's flood hypothesis. *GSA Today* 12:4–10.

Ballard, R. D., D. F. Coleman, and G. Rosenberg (2000). Further evidence of abrupt Holocene drowning of the Black Sea shelf. *Marine Geology* 170:254–61.

Ballard, R. D., F. T. Hiebert, D. F. Coleman, C. Ward, J. S. Smith, K. Willis, B. Foley, K. Croff, C. Major, and F. Torres (2001). Deepwater archaeology of the Black Sea: the 2000 season at Sinop, Turkey. *American Journal of Archaeology* 105:607–23.

Basch, L. (1987). *L'Musée Imaginaire de la Marine Antiqué*. Athens: Institute Hellénique pour la Préservation de la tradition nautique.

Bascom, W. (1976). *Deep Water, Ancient Ships*. Garden City, NJ: Doubleday.

Bass, G., and F. H. van Doorninck, Jr. (1982). *Yassi Ada: A Seventh-Century Byzantine Merchantman* I. College Station, TX: Texas A&M University Press.

Casson, L. (1994). *Ships and Seafaring in Ancient Times*. London: University of Texas Press.

Codispoti, L. A., G. E. Friederich, J. W. Murray, and C. E. Sakamoto (1991). Chemical variability in the Black Sea: implications of continuous vertical profiles that penetrated the oxic/anoxic interface. *Deep Sea Research,* 38:S691–S710.

Coleman, D. F. (2002). Underwater archaeology in Thunder Bay National Marine Sanctuary, Lake Huron—preliminary results from a shipwreck mapping survey. *Marine Technology Society Journal* 36:33–44.

Coleman, D. F., J. B. Newman, and R. D. Ballard (2000). Design and implementation of advanced underwater imaging systems for deep sea marine archaeological surveys. In *Oceans 2000 MTS/IEEE Conference and Exhibition*, I, 661–5. Piscataway, NJ: IEEE Oceanic Engineering Society.

Doonan, O. (2004). *Sinop Landscapes: Exploring Connection in the Black Sea Hinterland*. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.

Facey, W. (1979). *Oman, a Seafaring Nation*. Muscat: Ministry of Information and Culture.

Friedman, Z. (2003). *Ship Iconography in Mosaics: An Aid to Understanding Ancient Ships and their Construction*. Thesis, Department of Maritime Civilizations, University of Haifa, Haifa.

Garlan, Y. (1998). Fouilles d'ateliers amphoriques à Nisiköy et a Zeytinlik (Sinop) en 1996 et 1997. *Anatolia Antiqua* 6:407–22.

Görür, N., N. Çağatay, Ö. Emre, B. Alpar, M. Sakınç, Y. İslamoğlu, O. Algan, T. Erkal, M. Keçer, R. Akkök, and G. Karlık (2001). Is the abrupt drowning of the Black Sea Shelf at 7150 yr BP a myth? *Marine Geology* 176:65–73.

Gianfrotta, P. A., X. Nieto, P. Pomey, and A. Tchernia (1997). *La Navigation dans l'Antiquité*. Provence: Publ?.

Grace, V. (1949). Standard pottery containers of the ancient greek world. *Hesperia*: Supplement 8:175–89.

Haldane, C. (1991). Recovery and analysis of plant remains from some Mediterranean shipwreck sites. In J. Renfrew (Ed.), *New Light on Early Farming*, ed. J. Renfrew, 214–23. Edinburgh: Edinburgh University Press.

Hiebert, F. (2001). Black Sea coastal cultures: trade and interaction. *Expedition* 43: 11–20.

Hiebert, F., D. Smart, A. Gantos, and O. Doonan (1997). From mountaintop to ocean bottom: a comprehensive approach to archaeological survey along the Turkish Black Sea coast. In *Ocean Pulse: A Critical Diagnosis*, ed. J. Tanacredi and J. Loret, 93–108. New York: Plenum.

Horlings, R. (2005). *Deepwater Survey, Archaeological Investigation and Historical Contexts of Three Late Antique Black Sea Shipwrecks*. Thesis, Department of Anthropology, Florida State University, Tallahassee.

Kassab Tezgör, D. (1996). Fouilles des atelier d'amphres à Demirci près de Sinope en 1994 et 1995. *Anatolia Antique* 4:335–54.

Kassab Tezgör, D. (1998). Prospection sous-marine près de la côte Sinopéenne: transport d'amphores depuis l'atelier et navigation en Mer Noire. *Anatolia Antiqua,* 6:443–9.

Kassab Tezgör, D. (1999). Types amphoriques fabriqués à Demirci prés de Sinope. *Production et Commerce des amphores anciennes en Mer Noire*, ed. Y. Garlan, 117–23. Provence: Publications de l'Université de Provence.

Kassab Tezgör, D., and F. Dereli (2001). Rapport de la fouille de Demirci-Sinop 2000. *Anatolia Antiqua* 9:215–25.

Kassab Tezgör, D., and I. Tatlican (1998). Fouilles des atelier d'amphores à Demirci près de Sinope en 1996 et 1997. *Anatolia Antiqua* 6:423–42.

Kassab Tezgör, D., and M. Touma (2001). Amphores exportées de mer Noire en Syrie du Nord. *Anatolia Antiqua* 9:101–15.

Kassab Tezgör, D., I. Tatlican, and H. Özdaş (1998). Prospection sous-marine près de la côte sinopéenne: transport d'amphores depuis l'atelier et navigation en mer Noire. *Anatolia Antiqua* 6:443–9.

Mindell, D., B. Foley, and S. Webster (1998). Black Sea survey: cruise report. Manuscript on file at the Massachusetts Institute of Technology and the Institute for Exploration, Mystic, CN.

Murray, J. W., H. W. Jannasch, S. Honjo, R. F. Anderson, W. S. Reeburgh, Z. Top, G. E. Friederich, L. A. Codispoti, and E. Izdar (1989). Unexpected changes in the oxic/anoxic interface in the Black Sea. *Nature* 338:411–3.

Oğuz, T., V. S. Latun, M. A., Latif, V. L. Vladimirov, H. I. Sur, A. A. Markov, E. Ozsoy, B. B. Kotovshichkov, V. N. Eremeev, and U. Unluata (1993). Circulation in the surface and intermediate layers of the Black Sea. *Deep Sea Research* I, 40:1597–612.

Peacock, D.P.S., and D. S. Williams (1986). *Amphorae and the Roman Economy*. London: Longman.

Pomey, P. (2006). The Kelenderis ship: a lateen sail. *International Journal of Nautical Archaeology* 35:326–30.

Riccardi, E. (2002). A ship's mast discovered during excavation of the Roman port at Olbia, Sardinia. *International Journal of Nautical Archaeology*, 31:268–9.

Roberts, O.T.P. (2006). The rig of the Kelenderis ship reconsidered. *International Journal of Nautical Archaeology* 35:330–1.
Ryan, W.B.F., W. C. Pitman III, C. O. Major, K. Shimkus, V. Moskalenko, G. A. Jones, P. Dimitrov, N. Gorur, M. Sakinc, and H. Yuce (1997). An abrupt drowning of the Black Sea shelf. *Marine Geology* 138:119–26.
Singh, H., J. Adams, D. Mindell, and B. Foley (2000). Imaging underwater for archaeology. *Journal of Field Archaeology* 27:319–28.
Steffy, J. R. (1994). *Wooden Ship Building and the Interpretation of Shipwrecks*. College Station, TX: Texas A & M University.
Uchupi, E., and D. A. Ross (2000). Early Holocene marine flooding of the Black Sea. *Quaternary Research* 54:68–71.
van Alfen, P. (1996). New light on the 7th-c. Yassi Ada shipwreck: capacities and standard sizes of LRA1 amphoras. *Journal of Roman Archaeology* 9:189–213.
van Doorninck, F. H., Jr. (1982). The hull remains. In *Yassi Ada: A Seventh-Century Byzantine Merchantman*, ed. G. Bass and F. H. van Doorninck. I, College Station, PA: Publ?.
van Doorninck, F. H., Jr. (2002). Byzantine shipwrecks. In A. Laiou (ed.) *The Economic History of Byzantium from the Seventh through the Fifteenth Century*, I, ed. A. Laiou, 899–905. Dumbarton Oaks Studies 39. Washington, DC: Dumbarten Oaks.
Ward, C., and R. Ballard (2004). Black Sea shipwreck survey 2000. *International Journal of National Archaeology* 33:2–13.
Zemer, A. (1978). *Storage Jars in Ancient Sea Trade*, Haifa: National Maritime Museum Publications.
Zoroğlu, L. (1994). *Kelenderis*, I. Ankara: Dönmez..