

CHAPTER 9

DEEP-SUBMERGENCE ARCHAEOLOGY

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INTRODUCTION

COASTAL waters represent the greatest danger to ships and seafarers, despite the persistence of a modern myth that has ancient mariners hugging the shore for safety (Davis 2000, 2009; Pomey 1997: 18–35; Wachsmann 1998: 295–301).¹ It is precisely here, at the intersection of water and shore, that ships are most commonly lost. It is doubtful that this fact was lost on ancient seafarers.

The open sea represents relative safety for a ship caught in a storm, for the vessel can attempt to outrun the weather. Ships can be overwhelmed by stormy conditions, but their survival rate in the open sea remains far more favorable, and most ships that come to grief do so within several hundred meters of a coastal obstruction (see, e.g., Acts 27:27–32). Apart from the dangers inherent in a lee shore, the perils of shore-based piracy in antiquity gave further incentive to avoid near-shore sailing (de Souza 1999; Ormerod 1987; Wachsmann 1998: 320–321). Thus, even long-haul coastal sailing had good reason to remain well out to sea, although probably staying in sight of land. Amphoras and other antiquities recovered from the depths in coastal waters by trawler nets presumably derive primarily from ships that sank along such sea lanes. Israel's Mediterranean coast is a good example of this phenomenon (Barag 1963; Gophna 2002; Safrai 1960; Zemer 1978). Other amphora would have reached the bottom as jetsam from passing ships (i.e., Spiess and Orzech 1981; Wachsmann et al. 2009).

Sailing over open water to and from islands located in the Mediterranean and its ancillary seas was already well established by the Neolithic period and in some

cases possibly much earlier (Strasser et al. 2010). Much of the evidence for this traffic derives from visitations to, and colonization of, islands (General: Cherry 1981, 1990; Cyprus: Simmons 1991, 2007: 232–263; the Aegean: Broodbank 2000; Broodbank and Strasser 1991; Davis 1992; Tzalas 1995; Tzamtzis 1990). Obsidian obtained on Melos and recovered from Mesolithic levels at Franchthi Cave, located in the southern Peloponnese, could only have arrived by means of water transport and is at present the earliest evidence for seafaring in the Mediterranean (Tzalas 1995: 459–462). The fact that Mesolithic sailor-prospectors reached Melos intimates that they also had a wide-ranging knowledge of other islands. The present seeming lack of Mesolithic remains on Mediterranean islands may be the result of global sea-level changes: most coastal sites dating to that era are now underwater and presumably covered with thick sediments (Broodbank 2000: 116; Firth in this volume).

Routes crossing the open Mediterranean required a sail of several days out of sight of land (Figure 9.1). One such route ran from Crete to Egypt and may have been in use by the end of the third millennium BCE (Pritchard 1969: 416; Vercoutter 1956: 420–421; Wachsmann 1998: 297–299).

Minoan fresco fragments from Tell el Daba (ancient Avaris) indicate extensive contact with Crete in the mid-second millennium, as does the appearance of Minoan emissaries depicted in Theban tombs as bringing their goods to Egypt during the reigns of Hatshepsut and Thutmose III (Bietak 1992, 1995; Bietak, Marinatos, and Palyvou 2000; Bietak et al. 2007; Vercoutter 1956; Wachsmann 1987). Vercoutter (1956: 51–53, 56–57, 81, 87–88, 91–92) notes that the Egyptians



Figure 9.1 Documented Bronze Age sea routes in the eastern Mediterranean. Data provided by the author. Illustration by D. Davis.

consistently identified these strangers with the “west” and that this strongly implies that the Minoans reached Egypt by sailing straight across the Mediterranean from Crete. Homer (*Od.* 14:252–258; 17:426) mentions this blue-water route twice and notes that it took five days. Classical sources describe the voyage as taking three to four days (Casson 1995: 287 n. 75).

Another documented Bronze Age Mediterranean open-water route stretched from Cyprus to Egypt. In the fourteenth century BCE, Rib-Addi, the embattled and loquacious king of Byblos, describes sending the Egyptian envoy Amanmasha from his court to Egypt in this roundabout manner, apparently to prevent the capture of the vessel by enemy ships patrolling the Syro-Canaanite coast (Wachsmann 1986). A geological survey of the Eratosthenes Seamount, which lies astride the Cyprus-Egypt route, raised granite and basalt rock samples that have been identified as ships’ ballast (Krashennikov et al. 1994: 118, 125 fig. 6.11: a–c, 126, 128; Mart and Robertson 1998: 702–703).

In 1976 the marine geologist Willard Bascom published a challenge to exploration. In a groundbreaking book published decades before its time, entitled *Deep Water, Ancient Ships*, he laid out a fascinating argument for the survival of shipwrecks of historical and archaeological significance in the depths of the Mediterranean and Black Seas. Based on his study of records kept by Lloyds of London during the mid-nineteenth century, he argued that not only might shipwrecks survive in better condition at great depths than in shallow waters, but also that they might be numerous (Bascom 1976: 71–84).

Of all the recorded ships that Bascom studied, about half sank. Some 80% of these did so in proximity to a coastal obstruction. A further 10% of the ships went down in open water, due to causes varying from the mundane to the utterly bizarre (Bascom 1976: 73–76; Regan 1993). The final 10% of ships lost at sea simply disappeared. Bascom notes that in most cases, however, the vessels had been observed heading into weather. Considering that no traces were found, he concludes that the majority of these sank in blue water, raising the possible percentage of deepwater wrecks to 20% of all those lost. As he notes, there is no reason to doubt that similar statistics apply to antiquity.

FROM SHIP TO SHIPWRECK: THE FORENSICS OF A DEEPWATER SHIPWRECK

It is worth pondering the forensic process by means of which a functional, wooden-planked ship becomes a stabilized deepwater shipwreck. Research on the effects of benthic biogenic degradation has been ongoing since the 1960s (Cullimore and Johnson 2008; Herdendorf, Thompson, and Evans 1995: 62–78, 159–163; Muraoka 1964, 1965, 1966a, 1966b, 1966c, 1967, 1969, 1970).

A vessel that sinks in deep water will not suffer damage by storms, waves, surges, strong currents, or the agencies of ancient salvagers, all of which have contributed to the scrambling, loss of artifacts, and outright destruction of so many shallow-water shipwrecks (Casson 1995: 252 n. 108, 370 n. 45; Frost 1968; Muckelroy 1978: 157–214; Pomey 1997: 42–43; Stewart 1999; Tchernia 1978; Martin in this volume). Rather, ships sinking in deep water will undergo a much gentler transition.

Changes may have occurred even before the vessel slipped beneath the waves. Marine borers and waterlogging may have already weakened the vessel's timbers (Herdendorf, Thompson, and Evans 1995: 100, 159–161). Rigging, masts, and sails may have been cut away during storms or in the aftermath of battles; cargoes may have been cast overboard in an attempt to lighten the vessel (see, e.g., Jonah 1:5; Acts 27:18). The discovery at Skerkie Bank near Sicily, and off Chrisi (Gadaranoussi) Island south of Crete, of lines of discarded amphoras represents the archaeological reality of a commonly described phenomenon (Ballard et al. 2000: 1594, 1595 fig. 2, 1607, 1617–1618; Foley and Ballard 2004; Wachsmann et al. 2009: 148, 149 fig. 2). If the ship sank as a result of a storm, items may have shifted greatly as the ship ran before the storm. Additionally, the manner in which the vessel slipped below the waves—upright, listing, capsized, bow or stern first—could result in the displacement of items.

The cargo-stowing abilities of the ancients must not be underestimated, however. Amphoras were designed, and constantly evolved, specifically for a nautical environment. Such cargoes would have been well secured and perhaps roped down through their handles, and cushioned with sufficient dunnage to protect from stormy weather (Pomey and Tchernia 1978; Rival, Hesnard, and Bernard-Maugiron 1988). Thus, the well-aligned rows of amphoras commonly seen on the wrecks of ancient merchantmen do not preclude these vessels having experienced severe weather prior to sinking.

Most wooden-planked ships that now exist at great depths must have reached the sea bottom in a more or less intact condition (Muckelroy 1978: 150, 166). The natural buoyancy alone of a wooden hull will result in her floating, unless she is carried down by her contents (ballast, cargo, cannon, etc.). Indeed, numerous reports exist of ancient warships—lacking cargo and only lightly ballasted—remaining afloat and being captured and towed away by the victors after they “sank” (Casson 1995: 82; Morrison and Williams 1968: 34–35, pls. 6: e, 7: a [Geom. 32, 38]; Wachsmann 1998: 167 fig. 8.5, 171 fig. 8.14). If, however, during the wrecking event a wooden-planked ship broke up and spilled her contents in deep water, only a debris field might remain on the seabottom to mark the event.

As a cargo ship sank in deep water, sealed amphora containing air-pockets would implode, perhaps forcing their sealing bungs inside (Bass 1986: 278 ill. 8). Light unattached objects not trapped between deck(s) and hull would float back to the sea surface as flotsam. Heavier items that fell free of the ship would sink at their own velocities and might come to rest at some distance from the shipwreck. In some cases these processes will have formed a visible debris trail (if not covered by subsequent sedimentation), which may aid in locating the wreck (Ballard 2008b: 97–104).

Anchors that had been deployed to keep the ship from broaching during a storm would hang below the ship during the descent and, depending on the speed of the current, might end up beneath the ship or at some distance from it (Acts 27:17, 29, 40). This may explain the location of a lead anchor stock found some 20 m from the main grouping of the Skerkie B shipwreck and the distance that a stone bow anchor lies from the Tanit ship's cargo spread (Ballard et al. 2000: 1599, 1600 fig. 5, 2002: 154 fig. 3; McCann and Oleson 2004c: 128 fig. 7.1, 131 fig. 7.3, 150, 151 figs. 7.44–45).

As the ship sank, she would have reached a terminal velocity based on her overall density and drag. RMS *Titanic*, for example, is estimated to have reached a terminal velocity of 25–30 mph (about 40–48 kmh) when she hit the seabed at a depth of 3,795 m (Uchupi, Ballard, and Lange 1988–1989: 59). Similarly, a study of the copper-clad SS *Central America* led to the estimate that it had taken the ship about 18 minutes from the time that she sank beneath the waves till her collision with the seabed, some 2,200 m below. The vessel's impact velocity is calculated at 7.3 kmh (Herdendorf, Thompson, and Evans 1995: 64).

In deep water, a sinking ship will tend to right herself and, therefore, will normally impact the seabed more or less on an even keel (R. D. Ballard, pers. comm.; Ballard et al. 2000: 1616). Just before the ship hits the bottom, if it consists of unconsolidated sediments, the pressure wave beneath the hull will blow a crater in the seabed sediment (J. Morris, pers. comm.). Craters, which are presumably relics of this phenomenon, have been recorded by means of microbathymetry on the late-eighth-century BCE Phoenician shipwrecks Tanit and Elissa, found at a depth of 400 m off the Mediterranean coast of Egypt (Ballard et al. 2002: 155 fig. 4, 157 fig. 6; Singh, Whitcomb et al. 2000: 156 fig. 4, 157 fig. 5). The force of the vessel's impact on the seabed may result in weakening, or even cracking the hull open. At the very least it is an additional opportunity for items to shift, particularly if the vessel hits the seabed bow or stern first.

Most of the Mediterranean's deep seabed consists of unconsolidated sediments. When landing on such a bottom, lower parts of the hull would be forced into the bottom by the kinetic energy of the collision. This would also raise a cloud of displaced sediment, some of which would sink back onto the ship, beginning the process of burying at least the lower parts of the hull.

Over time, additional sediments will continue to filter down onto the shipwreck. Currents may scour sediments away from some parts of the wreck (or from artifacts) or cause them to accumulate in other areas (Ballard et al. 2000: 1616–1618; Herdendorf, Thompson, and Evans 1995: 70 fig. 69, 77 fig. 76). If the rate of sedimentation is high, the wreck may be buried entirely, making it nearly impossible to locate and study with present technology.

Parts of the ship's hull that remain exposed in the water column undergo a gentle disintegration as the result of two primary phenomena: marine borers and the waterlogging of her timbers. All of the timbers' water-soluble components—starches, organic acids, and sugars—leach out (Grattan 1987). Bacteria, and to a lesser degree fungi, subsequently consume the cellulose (Herdendorf, Thompson, and Evans 1995: 80–82; Kohlmeyer 1969; Wessel 1969). Eventually, even lignin, the

skeletal part of the wood cell walls, disintegrates. Wood-boring organisms, mainly deepwater boring mollusks (family Pholadidae), aid and abet this process by tunneling into the wood. As most of the biological activity takes place in the first meter above the seabed, the hull will disintegrate first in the area nearest to the seabed, so that if one could observe the process in time-lapse photography, the hull would seem to disappear into the seafloor (Muraoka 1970: ii, 5–6, 12 table 3). As these processes continue, the actual percentage of wood in a timber diminishes until nothing remains but the calcareous mollusk burrows (Herdendorf, Thompson, and Evans 1995: 98, 100, 154, 155 fig. 136, 156 figs. 137–138, 157). As there is a deficiency of calcium carbonate at depth, even these burrows will eventually disappear, having dissolved into the surrounding water column (Morse and Berner 1972).

Although the degradation of the wood will be a gradual process, cataclysmic events will occur as portions of the hull weaken and fall off in sections. These sections of hull will be buried under collapsing cargo and equipment, or remain exposed on the seabed and rapidly disintegrate (Herdendorf, Thompson, and Evans 1995: 65, 156 fig. 138).

No longer constrained by the hull, cargo will disperse accordingly. Items carried on deck or in castles will come to rest on top of, or next to, the contents stored in the hull (e.g., Tanit and Elissa wrecks: Ballard et al. 2002: 154 fig. 3 [upper right], 158 figs. 7.1–3, 159 fig. 8, 160 figs. 9.1–3, 7–10, 161; SS *Central America*: Herdendorf, Thompson, and Evans 1995: 65). If the ship lists only slightly and if the amphoras are tightly packed, they might simply “lean” to one side. Whether lying horizontally or vertically, open amphoras can fill up, acting as sediment traps as current-borne particles that enter their mouths decelerate and settle out inside them (J. K. Hall, pers. comm.).

As with shallow-water shipwrecks, in normal conditions the preservation of the hull, and of other organic items aboard, will be limited to those portions buried in the anoxic sediment soon after the sinking. In other words, the lower portions of a deepwater hull might be expected to survive in a manner analogous to those of better-preserved shallow-water shipwrecks that sink into soft sediments away from surface turbulence (Bascom 1976: 105–118).

Timbers recovered from Roman period Skerkie Bank shipwrecks demonstrate that wood from antiquity can survive at depth if rapidly buried in the sediment (Bascom 1976: 105–118; McCann 1994b: 11 fig. 9, 12 figs 10–11, 13; McCann and Oleson 2004c: 150–151, 152 figs. 7.46–48; McCann and Oleson 2004d: 87, 88 figs. 4.63:a–b, 64; Piechota and Giangrande 2004: 201). The situation in the anoxic levels of the Black Sea and in very cold waters, such as the Baltic Sea, is exceptional at preserving timbers even in the water column, as seen on the Sinop D shipwreck in the former sea and an intact seventeenth-century Dutch *fluit* and other, more recent wrecks in the latter (Sinop D: Ballard et al. 2001: 619–621; Coleman, Ballard, and Gregory 2003: 1288 fig. 3; Davis 2008: 79–82; Ward and Ballard 2004: 6–12; Ward and Horlings 2008: 160–165; Baltic: Hagberg et al. 2007; Rönnby 2008).

As copper and its alloys tend to retard the attack of marine borers on shipwrecks, a cargo of copper ingots similar to the lading of the Uluburun shipwreck, or a bronze ram,

might be expected to aid in the preservation of nearby timbers (Herdendorf, Thompson, and Evans 1995: 66; Pulak 1999b: 212; Uchupi, Ballard, and Lange 1988–1989: 57). If left unburied by sediment, organic cargoes, which may have comprised a considerable percentage of a ship's total cargo, will be consumed and disintegrate, becoming "invisible" and leaving areas of the wreck site seemingly empty. This is the most likely explanation for the gaps noted between clusters of artifacts on the Skerkie D shipwreck (Ballard et al. 2000: 1603 fig. 7, 1608–1609; McCann and Oleson 2004d: 53). Eventually, however, the wreck will reach a state of equilibrium, with the upper works gone and the buried remains securely interred.

Subsequently, the wreck will be affected solely by geological phenomena or human interventions. Many shipwrecks now lie buried beneath meters of sediment and at present are invisible and unattainable with even the most advanced technology. Human intervention can cause devastating damage to shipwrecks even in deep water. While treasure hunters are the most conspicuous despoilers, other more mundane human enterprises can destroy deepwater shipwrecks inadvertently and are just as damaging and infinitely more common. Trawlers represent by far the most serious anthropogenic threat to deepwater shipwrecks; additional dangers to shipwreck may result from the laying of pipelines or cables, the construction of deepwater facilities for power plants, and even the anchor drag of large ships (Gibbins 1991: 167 n. 1; Hiney 2002: cover, 2–12; Smith, Banks, and Banks 2007; Stewart 1999).

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Until the last few decades, the archaeological investigation of shipwrecks has been largely limited to those located in depths achievable by diving archaeologists (Bass 1976a: 111–123, 169–184; Delgado 1997; Gibbins 1991: 166–167; Long 1987, 1988, 1998; Pomey 1997: 44). More recently, a number of archaeologically and historically significant shipwrecks lying at depth have been located and studied to various degrees (e.g., Skerkie Bank: McCann and Freed 1994; McCann and Oleson 2004a; the Tanit and Elissa wrecks: Ballard et al. 2002; Stager 2003; Chios: Foley 2008; Foley et al. 2009; Sakellariou et al. 2007: 365–373, 379–380; Egadi Islands (off Sicily): Anonymous 2009; Royal 2008; Ventotene (Italy): Flynn 2009; Black Sea: Davis 2008; Ward and Horlings 2008; Trondheim Harbor: Søreide 2000; Norwegian Sea: Søreide et al. 2006; modern shipwrecks: Ballard 2008b; Ballard and Archbold 1987; Bryant and Hamilton 2007; Church and Warren 2008; Church et al. 2002, 2003, 2004; Ford et al. 2009; Ford, Borgens, and Hitchcock 2010; Jourdan 2009; Warren, Church, and Davey 2004).

Deep-submergence archaeology (DSA), the term given here to the archaeological study of cultural resources beyond the limits of traditional diving, may also contribute to our understanding of the distant human past, when much of the

Earth's water was locked in ice sheets, causing the ocean system to drop significantly. Human habitation sites may exist in areas that are now in deep water (Coleman 2008a, 2008b; Coleman and McBride 2008; Faught and Flemming 2008; Largent 2009, 2010; Ryan et al. 1997; Ryan and Pitman 1998; Firth in this volume).

Of course, each nautical archaeologist could generate a list of shipwrecks at great depths worthy of study based on their own research interests. For scholars interested in seafaring of the early Mediterranean, shipwrecks supplying a relatively complete picture of a vessel and her contents remain rare prior to the sixth century BCE, and hull remains are even scarcer. The Uluburun ship, dating to the last quarter of the thirteenth century BCE, carried a rich cargo and remained sufficiently intact to recover parts of her hull, which indicate that her builders used an already remarkably developed form of pegged mortise-and-tenon joinery to edge-join the hull planking (Fitzgerald 1996; Pulak 1999a, 1999b; Steffy 1994: 36–37). Dated about a century later, the more poorly preserved Cape Gelidonya shipwreck may have broken up during the sinking event; but the hull remains, though they consist of only a few wood fragments, are sufficient to indicate that her builders also used a similar form of construction (Bass 1967: 45, 48 figs. 45–46, 49 fig. 48, 50 fig. 51; Pulak 1999b: 214, 219–220, 232 table 1, 237 fig. 6; Wachsmann 1989: 192, 1998: 217, 218 fig. 10.3). Other Bronze Age “shipwrecks” are in truth better described as cargo scatters, or materials derived from nearby land sites, and contribute nothing to our understanding of ancient ship construction (Dokos: Papathanassopoulos, Vichos, and Lolos 1995; Vichos and Papathanassopoulos 1996; Sheytan Deresi: Bass 1976b; Catsambis 2008; Margariti 1998; Cape Iria: Phelps, Lolos, and Vichos 1999; Vichos 1999; Vichos and Lolos 1997; Pseira: Bonn-Muller 2009; Hadjidaki and Betancourt 2005–2006). Valuable though these sites may be in terms of archaeological data, they cannot be considered coherent shipwrecks.

Subsequently, the record of relatively intact hulls only picks up again in the seventh century BCE. From this time, we have a series of vessels: Mazarrone (circa seventh century BCE, Aizpurua and Méndez 1996; Negueruela 2000a: 182–184; Negueruela 2000b), Bon-Porté and Pabuç Burnu (late sixth century BCE, Bass, Carlson, and Polzer 2006: 139; Bound 1985, 1991; Greene and Polzer 2004; Polzer 2004, 2005, in press), Place Jules Verne–9 and Place Jules Verne–7 (last quarter sixth century BCE, Pomey 1997: 90–93), and Gela (circa 500 BCE, Freschi 1991, 1996). Additionally, an intriguing Phoenician wreck dating to the late seventh or early sixth centuries BCE is currently under excavation at Bajo de la Campana, Spain, and one may hope for hull survival at this site also (Mas 1985; Polzer 2007, 2008, 2009; Polzer and Reyes 2007; Roldán Bernal, Miñano Domínguez, and Martín Camino 1991; Roldán Bernal, Martín Camino, and Pérez Bonet 1995). Thus, regarding ancient Mediterranean shipwrecks, virtually any vessel predating the seventh century BCE discovered in deep water would be of sufficient archaeological and historical significance to make her worthy of study.

These considerations put into perspective the remarkable discovery of not one, but two late-eighth-century BCE Phoenician shipwrecks found in deep water by the crew of the NR-1 off the northern coast of Egypt in 1997 and subsequently stud-

ied by Ballard and Stager in 1999 (Ballard et al. 2002; Gore 2001: 91–93; Stager 2003). Dating to about the time when Homer is believed to have written his epics, not only are these vessels exceptional in being the first Levantine Phoenician shipwrecks found, but they also date to a century for which we have no other recorded shipwrecks.

Deep-submergence archaeology is indeed more costly than a conventional shipwreck excavation, but there are significant trade-offs. A variety of factors—daylight hours, decompression, and cold, to list but a few—limit conventional shipwreck excavations. On the other hand, DSA is a round-the-clock operation, with control teams working in shifts. Once a remotely operated vehicle (ROV) reaches the seabottom, barring truly inclement weather or the unexpected, work can continue uninterrupted on a 24-hour work schedule (Figure 9.2). Additionally, an ROV or an autonomous underwater vehicle (AUV) can carry out site recording, which takes up an extraordinary amount of total bottom-time on any conventional underwater excavation, far more effectively than archaeological divers (Figure 9.3) (Ballard et al. 2000: 1602, 2002: 154; Foley et al. 2009; Singh, Pizzaro et al. 2000; Warren and Church 2003; Warren, Church, and Westrick 2008; Yoerger et al. 2007).

Some might argue that no ship in deep water should be touched until all the appropriate excavation tools have been developed. However, technology does not develop on its own: it is purpose-driven and can be improved upon only by initiating actual work. Additionally, this approach leaves the deep seas open to treasure hunters, while excluding nautical archaeologists, which is clearly an unacceptable

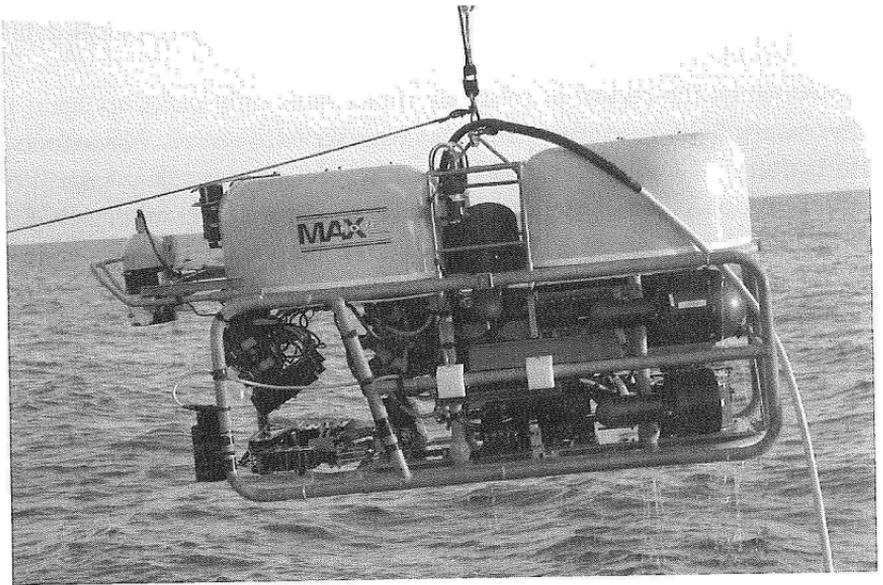


Figure 9.2 This MaxRover class remotely operated vehicle (ROV), owned by Greece's Hellenic Centre for Marine Research (HCMR), has been used effectively for checking anomalies and for other archaeological purposes. It is rated to 2,000 m.

Photograph by the author.

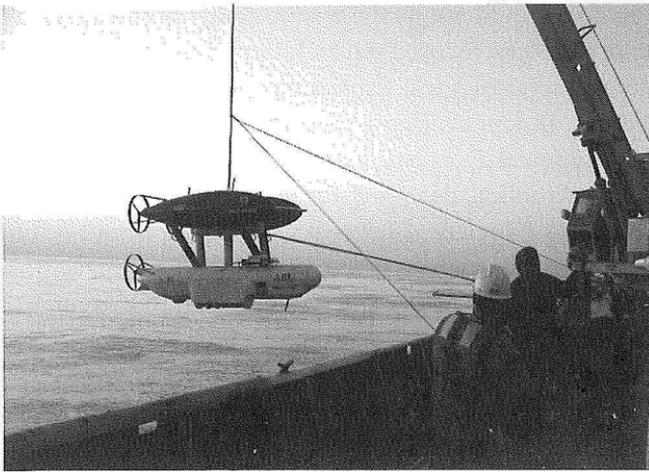


Figure 9.3 Recovery of Woods Hole's Autonomous Benthic Explorer (ABE) Autonomous Underwater Vehicle (AUV). Reproduced with kind permission of the WHOI/ABE Group.

situation. Given present realities, by not expanding into these new areas, the archaeological community would be harming its own interests.

Archaeologists have lagged behind treasure hunters in the race to develop and carry out strategies for excavating shipwrecks at depth (e.g., *SS Central America*: Herdendorf, Thompson, and Evans 1995; Kinder 1998; Thompson 1998; wreck identified as the *Buen Jesus y Nuestra Señora del Rosario*: Moore 1997; the Black Swan wreck: Colapinto 2008). Treasure-hunting groups have developed their own technologies for retrieving and raising artifacts from the deep-sea floor. As tools for exploring and exploiting the deep seas continue to develop rapidly, and become cheaper to purchase and operate, treasure-hunting initiatives will continue to expand aggressively into the deep sea. These regions are appealing, as deep waters to a large degree are synonymous with international waters and, therefore, at present at least, lie largely beyond the reach of governmental controls and restrictions (Elia 2000; Irion 2002; Irion, Ball, and Horrell 2008; McCann and Oleson 2004b: 23–24; O'Keef 1999). Unless something is done to change this trend, we stand the danger of losing the final frontier of archaeology (Colapinto 2008; Goodheart 1999; Koerner 1999).

At the risk of stating the obvious, the archaeological excavation of a shipwreck at depth is a highly complex affair, requiring diverse areas of expertise. The role of the archaeologist within this multidimensional operation requires a paradigm shift. In conventional excavations, be they terrestrial or marine, the principal investigator normally bears the overall responsibility for the entire expedition. The new paradigm, however, calls for a somewhat different approach—one in which the archaeologists are the specialists brought to the site by the oceanographers. A good analogy may be the relationship between submariners and “spooks” in naval intelligence-gathering missions (Sontag, Drew, and Lawrence-Drew 1999). Just as is not the role of the intelligence gatherers to drive submarines, similarly, running technical

aspects of the project should not be the responsibility of the archaeologists. Rather, their responsibility must be focused on, and limited to, the archaeology.

The totality of archaeological exploration at great depths—discovering, recording, excavating, and recovering—requires function-specific tools. Deep Submergence Archaeological Excavations (DSAE), however, takes advantage of a remarkable existent toolkit, designed for a variety of oceanographic purposes other than the study of ancient shipwrecks. Truly, we would not be considering DSAE at all were it not for such advances as side-scan sonar, bottom-penetrating sonar, Differential Global Positioning System (DGPS), dynamic positioning, fiber optics, high-definition video, ROVs, and a host of other technologies (Coleman and Ballard 2008; Newman, Gregory, and Howland 2008).

Viewed from this perspective, missing technologies remain challenging yet relatively minor problems. Deepwater archaeological survey is already at an advanced stage. Through experience and experimentation, strategies for locating shipwrecks in deep water have developed considerably in recent years (Ballard 2008a, 2008b; Herdendorf, Thompson, and Evans 1995: 46–52; Jourdan 2009; Sakellariou 2007–2008; Sakellariou et al. 2007).

What *is* lacking at present is a comprehensive methodology for deepwater excavation. In addition, it seems to me that the most important element to bring with us in approaching wrecks at depth is a sincere and intense sense of humility. We are poised to reach back to human treasures that have not been seen since they sank. In such a situation it is important to remember that just because a technical ability exists, it does not necessarily have to be used. The ultimate goal of DSAE will be to develop the technologies and the skills that will permit expeditions to excavate and safely raise the contents and hull of an entire ship for conservation, study, and display. The technological toolkit to accomplish this remains years away, if not decades. Yet the future ability to reach this goal should dictate present steps.

For the purpose of this discussion, let us imagine a deepwater shipwreck of unique archaeological/historical significance to make it a worthwhile candidate for excavation. This wreck lies on a flat abyssal plain of negligible gradient consisting of unconsolidated sediments. A significant portion of the hull survives buried in the sediment beneath the wreck's inorganic contents. These may include anchors, amphoras, pithoi, ingots, stone blocks, pillars, ballast, and the like. Embedded in this matrix are numerous smaller artifacts, down to the size of a bead. That these minute artifacts are hardly a theoretical concern is demonstrated by the thousands of beads found scattered throughout the Uluburun shipwreck (Ingram 2005; Pulak 1997: 245).

A shipwreck must be considered a complex artifact rather than a habitation site (Muckelroy 1978: 215–225). For that reason, most nautical archaeologists will prefer to excavate an entire shipwreck. At this pioneering stage, however, it would be premature to excavate an entire deepwater shipwreck. Rather, by excavating several controlled archaeological sections, an expedition will be able to address the most pertinent questions raised by a shipwreck: the date, the source(s) of the cargo, the last itinerary, the cultural identity of the vessel's home port, and the construction techniques used in the building of the hull.

If we lack a vessel's ethnic identity, it is difficult to evaluate a ship's historical significance. Yet one of the most perplexing problems that arise in the archaeology of ancient ships remains the identification of a vessel's homeport. Cargoes are of little value in determining a homeport, as a ship can carry a cargo loaded at any port. A Late Bronze Age vessel loaded to the caprails with Mycenaean Greek stirrup jars, for example, might have traded them at the last port of call for a cargo of Syro-Canaanite copper-oxide ingots from the home port (Bass 1967: 165). For Mediterranean Bronze and Iron Age ships there are several indicators that, taken together, might help determine ethnic identity, including personal items belonging to the crew and passengers, balance-pan weight sets, cultic items, and stone anchors or killick stones (Bachhuber 2006; Bass 1967: 163–167; Pulak 1996, 1998, 2008: 300–302; Wachsmann 1998: 211–212, 2000: 815–820). With the notable exception of the anchors, most of these items normally would have been located at the stern, which traditionally served as the crew's quarters.

As hulls narrow at their extremities, resulting in structural changes, the best location to learn about the vessel's construction is found amidships. Excavators should take advantage, however, of any locations where hull remains might be reached with minimal excavation as, for example, areas covered only by stone anchors, or a layer of ballast stones.

Prior to excavation, an accurate site plan must be generated. Advanced solutions have been developed for this purpose (Ballard 1993; Ballard et al. 2000; Foley et al. 2009; Mindell et al. 2004; Singh, Adams et al. 2000; Singh, Romans et al. 2000, 2008; Singh, Howland, and Pizarro 2004; Whitcomb, Yoerger, and Singh 1999a, 1999b; Whitcomb et al. 1999).

The very nature of photomosaics precludes their use for accurate measurements (Bass 1982: 21–22; Singh, Adams, et al. 2000: 321–322). Accurate site plans can be generated from the optical data by means of stereophotogrammetry, a method that has been in use for many years in shallow-water excavations (Bass 1976a: 96–97, 103–106, 1982: 24–26). For this purpose, the merging of microbathymetric maps with optical data may be the solution (Singh, Whitcomb et al. 2000; Singh, Roman et al. 2000; Mindell et al. 2004).

In an ideal world, archaeologists could get a virtual “sneak peak” into a shipwreck before the onset of excavation to permit them to formulate the best excavation strategy. A prototype high-frequency, narrow-beam sub-bottom profiler designed for this purpose was first deployed on *Jason* during the 1999 survey of the Tanit and Elissa wrecks (Mindell and Bingham 2001). Further refinement of such a device, and a better understanding of the data it generates, could significantly enhance predisturbance examination.

DSAE requires creative robotic solutions to handle a bewildering assortment of situations and artifacts that may vary considerably in size, weight, volume, brittleness, and structural strength. Solutions to raising many types of artifacts already exist.

Any artifact that is moved in the context of excavation must first receive some form of firmly secured identification (Wachsmann 2007–2008: 137 fig. 6). Repeat

optical recording of a depot has been employed to record the few artifacts that might be moved and stored during an archaeological survey of a wreck (Singh, Adams et al. 2000: 326 fig. 6). An excavation, however, will generate too many displaced objects to depend solely on this manner of recording. Additionally, pottery on deep shipwrecks undergoes stress resulting from benthic processes not normally encountered in ceramics from shallower wrecks (Ballard et al. 2000: 1614–1616; Piechota 1994; Piechota and Giangrande 2004: 196–197, 2008). Thus, the fragility of these artifacts also must be taken into consideration when stockpiling them: an artifact might shatter even during the most careful handling.

The process of excavation favors a method of stabilizing the ROV on site, and several versions of frameworks or railing have been developed for this purpose (Alfsen 2006; Coleman, Ballard, and Gregory 2003: 1289, 1290 fig. 9; Søreide 2000; Søreide, Jasiński, and Sperre 2006: 11–12; Webster 2008: 57 figs. 4.18–19).

Two distinct actions compose controlled underwater excavation: the gentle raising of sediment into the water column without harming or moving the artifacts embedded in it, and the transportation of the sediment off-site. To transport off-site the large quantities of sediment generated by the excavation, a Venturi dredge is the tool of choice: it is commonly used on conventional underwater excavations in water too shallow to allow for an airlift (Breitstein 2003: 12 fig. 5 and n. 8, 14 fig. 7; Dean et al. 1992: 211–213, 310–312). The dredge's task is not to excavate into the sediments, but rather to act as a slurry conveyer belt to transport sediments off-site after they have been raised into the water column by other methods. The slightest disturbances of these unconsolidated sediments—the movement of an amphora, for example—raises clouds of fine silt that remain suspended in the water until it settles out and/or is transported off-site by the current (Ballard et al. 2000: 1607). This phenomenon lowers visibility to the degree that work must often cease. Thus, in a low-velocity current this problem alone can result in a significant drop in on-site productivity. Solutions have been developed to solve this problem (Herdendorf, Thompson, and Evans 1995: 54). The most recent of these is the “snuffler” excavation tool, which sucks up the suspended silt as it is being excavated (Figure 9.4; Coleman, Ballard, and Gregory 2003: 1289–1290; Webster 2008: 49–55).

A diving archaeologist has three-dimensional vision and tactile sense. Two forward-facing cameras on the ROV *Nemo* generated a three-dimensional image that, upon transmission to an optically polarized monitor, created a three-dimensional display (Herdendorf, Thompson, and Evans 1995: 57–58). Similarly, the ROV *Hercules* allows the pilot the option of force feedback manipulation (B. Buxton, pers. comm.).

Cases may arise when it might be preferable to raise a group of small artifacts in their in situ spatial arrangement. Thus, on the SS *Central America*, *Nemo* raised gold coins in their original stacking position by placing an open-bottomed aluminum mold with a form-fitting skirt of soft material over the selected feature and then injecting the mold with liquid silicon (Herdendorf, Thompson, and Evans 1995: 53–54, 58 figs. 49–50, 59 fig. 51). For larger items, ROVs can employ simple yet remarkably dexterous tools like those developed for *Jason*, nicknamed the “Cowcatcher” and



Figure 9.4 The ROV's left robotic arm holds the "snuffler" in place to collect suspended sediment as the right robotic arm gently brushes away sediment clinging to timbers on the Sinop D shipwreck, Black Sea. Reproduced with kind permission of the Institute for Exploration and University of Rhode Island Center for Ocean Exploration and Archaeological Oceanography, URI Graduate School of Oceanography.

"Deep Spank" (McCann 1994a: 97, color figs. 12, 27; Webster 2008: 58, 58 fig. 4.20–21). These can be deployed safely to retrieve a wide range of artifacts varying in size and weight, from an amphora to an oil lamp. A hydraulic suction cup may be used to safely raise medium-sized artifacts, up to the size of an amphora, while an interchangeable tool set for use with an ROV's robotic arm adds additional functionality (Wachsmann 2007–2008: 139 fig. 8; Webster 2008: 55, 56 figs. 4.15–17, 57).

A highly controlled system is required to raise particularly heavy items without damaging them or their immediate surroundings. Prior to the excavation of the SS *Central America*, *Nemo* raised the ship's bell, weighing 125 kilograms (Herdendorf, Thompson, and Evans 1995: 51, 52 fig. 38, 53 fig. 39). How this procedure affected the surrounding hull is not reported. Bronze Age anchors may weigh up to half a ton (Wachsmann 1998: 255–293). Heavy metal items, such as copper ingots, might con- crete together to a degree that it would be preferable to raise them as a consolidated unit, rather than individually. During the excavation of the Cape Gelidonya ship- wreck, the archaeologists removed a group of concreted oxhide ingots as a single lump and then separated them on land (Bass 1967: 28 figs. 11–12, 29 figs. 13–16). Ex- cavators might find anchors or ingots stored in the hull, separated from the hull planking only by a thin layer of dunnage and/or ballast stones; even in a shipwreck with minimal hull preservation, such items may be expected to have pressed the portion of the hull beneath them into the sediment, and thus preserved it, as in the case of the Uluburun shipwreck (Pulak 1998: 212 fig. 24, 1999b: 212). Thought should also be given to the potential need to strengthen badly corroded artifacts prior to retrieval (Peachey 1990).

Paleoethnobotanical materials uncovered during an excavation can contain valuable clues to shipboard life and ghost cargoes (Uluburun: Haldane 1990, 1993; Pulak 2008: 295–296; Madrague de Giens: Tchernia et al. 1978: 112–118; Skerkie Bank: Beck, Stewart, and Stout 1994; Ward 2004; Tantura Lagoon: Bryant 1995; Wachsmann and Kahanov 1997: 14; Wachsmann, Kahanov, and Hall 1997: 11; Yassiada: Bryant and Murry 1982; Bozburun: Gorham 2000a, 2000b; the *Betsy*: Weinstein 1992; Mardi Gras: Ford et al. 2009: 164–173). Additionally, discolored patches of sediment, which have been noted on both shallow- and deepwater wrecks, may indicate decomposed materials and should be retrieved for study (Ballard et al. 2000: 1612; McCann and Oleson 2004e: 101; Pulak 1989: 6–7). DNA information may also be collected remotely (Foley et al. 2009).

Wood—be it hull timbers, dunnage, or firewood—may survive beneath cargo and gear. Branches used for onboard firewood and other purposes that would have been cut close in time to the ship's loss are particularly valuable for dendrochronological study (Kuniholm 1997; Kuniholm et al. 1996; Pomey 1998; Pulak 1998: 213–214). Leather products also tend to escape attack by benthic organisms, presumably due to the tannic acids used in their curing process (Ballard and Archbold 1987: 207, 218; Herdendorf, Thompson, and Evans 1995: 163 fig. 146, 164 fig. 147, 165 figs. 150–151).

Lowly bilge mud may be one of the most valuable sources for learning about a ship's history. Composed of detritus collecting primarily amidships, it may contain information on shipboard life hidden in a potpourri of spilled cargoes, garbage, and coprolites containing pollen, phytoliths, fungi, and a collection of other plant remains. Bilge mud stands out quite clearly on a shipwreck buried in sand (Wachsmann and Kahanov 1997: 14 fig. 16). It might be difficult to identify it in benthic sediment, so care should be taken to collect all the sediment in the areas where it tends to collect (along the keel/keel-plank and wedged between frames and planking). Control core samples must be retrieved from the seafloor around a shipwreck during the predisturbance survey to ensure against contamination (Davis 2008: 76, 77 fig. 7; Wachsmann 2007–2008: 141 fig. 10; Webster 2008: 46–49). Artifacts may be retrieved to the surface by means of an “elevator,” a device designed to raise items without requiring the ROV to break surface (Figure 9.5; Ballard 1993: 1680 fig. 4, 1683, 1998: 38; Bowen et al. 2000; Ford et al. 2009: 22–23; Webster 2008: 44–45). As excavation proceeds, the hull should be kept cradled in its outer sedimentary matrix, as the timbers will not have sufficient structural strength to support their own weight. Robotically applied polysulfide molds could be used to record hull structure underwater (Murdoch and Daley 1981, 1982).

To learn even more about the construction of the hull, consideration should be given to raising a section across it in the manner carried out on the Madrague de Giens shipwreck (Pomey 1978: 76–80 figs. 10–11, pl. XXVIII: 2). Robotically raising a hull-section intact from great depth might be considered the single most complex task to be accomplished at the present stage of technological development. It is important to emphasize that such a project on a deepwater shipwreck of

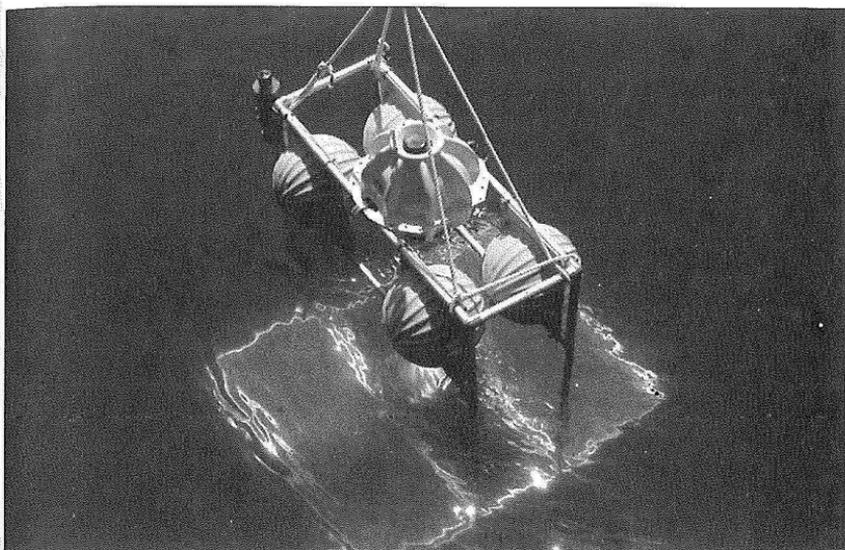


Figure 9.5 An elevator with artifacts in its containers rising from the sea. Reproduced with kind permission of the Institute for Exploration and University of Rhode Island Center for Ocean Exploration and Archaeological Oceanography, URI Graduate School of Oceanography.

archaeological/historical significance should be attempted only after careful consideration and only following much experimentation on a “sacrificial” wreck of *relatively* negligible significance. Due to the structural weakness of waterlogged wood, the safest retrieval method for this envisioned section might be to encase it prior to retrieval (Wachsmann 2007–2008: 139, 142, 144).

At the end of any excavation that reveals ship’s timbers and other organic materials, the excavated section of the hull must be reburied to ensure that exposed timbers do not fall prey to benthic organisms and that cargo does not shift due to currents. One method used successfully on shallow-water shipwrecks is to cover the timbers with a layer of synthetic sandbags (Breitstein 2003: 16 fig. 10, 17 fig. 12, 18 fig. 13; Grenier, Bernier, and Stevens 2007: 149–152). An ROV could deploy beanbag-sized sacks complete with Velcro tabs that cause them to “coagulate” on contact with each other. These bags could be filled with copper pellets to further repel marine borer larvae.

PUBLICATION

The results from the archaeological project must be presented in a final scientific excavation report, and disseminated to the general public as well. Given the highly digital nature of DSAE, which depends on electronic recording, such an

excavation would be ideally positioned to take the lead in examining the many exciting possibilities in employing electronic media before the general archaeological community. Directions for this potential include, but are not limited to, the following possibilities:

- Color photographs are prohibitively expensive to publish in most scientific reports. By using electronic media or a Web site, however, an archaeological report could include an almost unlimited number of color images.
- A selection of the most significant artifacts raised could be recorded as three-dimensional computer-generated models for a “virtual” museum. The user could manipulate an architect’s avatar as if the artifact itself were held in the hand (Wachsmann, in press).
- Three-dimensional constructs of the excavation area could demonstrate to the viewer the general lay of the land and the spatial relationships between artifacts in situ (e.g., VIZ-Tantura). Taking this one step further, clicking on an artifact would take the viewer to information about it. Alternately, the viewer could call up site plans displaying the spatial relationships of differing types of artifacts.
- Footage of the excavation process can be provided via streaming video from a Web site to purchasers of the publication, or to create documentary movies (Aig and Haywood 2008). Well-indexed video would permit the reader to call up the materials regarding the discovery and find location of any given artifact. When translated into a virtual reality format, it would allow the user to experience the excavation.

All of the above possibilities—and there are others, such as site-specific role-playing games for children and live Web sites—can be served up in popular formats for the general public and for educational purposes, contributing to the cultural awareness of DSA’s value (Corbin and Smith 2008; Hall 2008). The possibilities are confined only by the limits of our imagination.

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NOTES

1. This article is an updated and condensed version of Wachsmann (2007–2008). It includes references to deep-submergence salvage operations from shipwrecks of archaeological and historical significance carried out by organizations for commercial gain. These are discussed here because they contain important information regarding documented benthic site formation processes on wooden-planked ships and other issues related to this discussion. These references do not condone the salvage of such shipwrecks for commercial profit, a practice that I believe to be antithetically opposed to the preservation and the understanding of the past.

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