

THE MICA SHIPWRECK: DEEPWATER NAUTICAL ARCHAEOLOGY
IN THE GULF OF MEXICO

A Thesis

by

TOBY NEPHI JONES

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

May 2004

Major Subject: Anthropology

THE MICA SHIPWRECK: DEEPWATER NAUTICAL ARCHAEOLOGY
IN THE GULF OF MEXICO

A Thesis

by

TOBY NEPHI JONES

Submitted to Texas A&M University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Approved as to style and content by:

Kevin J. Crisman
(Chair of Committee)

Donny L. Hamilton
(Member)

William R. Bryant
(Member)

David L. Carlson
(Head of Department)

May 2004

Major Subject: Anthropology

ABSTRACT

The Mica Shipwreck: Deepwater Nautical Archaeology
in the Gulf of Mexico. (May 2004)

Toby Nephi Jones, B.A., Oregon State University

Chair of Advisory Committee: Dr. Kevin J. Crisman

The purpose of this study was to describe the investigation of the Mica shipwreck. The objectives of the investigation, as identified by nautical archaeologists from the United States Minerals Management Service and the Nautical Archaeology Program at Texas A&M University, include determining the extent and limits of the wreck site, acquisition of diagnostic artifacts to identify the temporal period of the shipwreck and its mission at the time of loss, to identify the type of ship and its country of origin, and quantify the relationship between the vessel's construction and function. The manuscript contains a thorough analysis of the equipment and approach used by archaeologists during the excavation.

The manuscript also briefly explores the use of metallic ship sheathing during the eighteenth and nineteenth centuries, focusing specifically on the pure copper sheathing found on the Mica wreck. Sheathing from numerous contemporary vessels will be analyzed and compared to the Mica shipwreck sheathing.

To my parents, Howard and Kathy

ACKNOWLEDGMENTS

Many people and institutions were instrumental in the planning and execution of the Mica shipwreck archaeological investigation. Dr. Kevin J. Crisman, a professor in the Nautical Archaeology Program at Texas A&M University, led the contingent of nautical archaeologists. His expertise, encouragement, and enthusiasm were instrumental in the successful completion of the project. Dr. William R. Bryant, of the Department of Oceanography at Texas A&M University, provided expertise relating to geological site formation processes affecting the Mica shipwreck, as well as heading the group of scientists from the Department of Oceanography. Dr. Jack Irion, Dr. Richard Anuskiewicz, and David Ball represented the Social Sciences Unit of the Minerals Management Service, the federal agency whose responsibilities include managing offshore cultural heritage, including shipwrecks. Dr. Donny L. Hamilton, head of the Nautical Archaeology Program at Texas A&M University, provided logistical support during the planning process. Brett Phaneuf, a research associate with the Department of Oceanography at Texas A&M University, was the project manager and performed the bulk of the logistical planning. Peter Hitchcock served as the chief conservator. Chris Felderhoff and Steve Christian, of the Offshore Technology Research Center, generously provided tools, space and expertise in the design and construction of the artifact retrieval system. Sandra K. Drews, of the Department of Oceanography at Texas A&M University, was extremely helpful throughout the entire operation. Dr. Renald

Guillemette, director of the Electron Microprobe Laboratory at Texas A&M University, expertly performed the composition analysis on numerous metallic sheathing samples.

The Mica shipwreck investigation represented a unique partnership between members of industry, academia, and the government/military. ExxonMobil Corporation provided a generous amount of funding, which served as the seed money from which to launch the investigation. Texas A&M University, represented by the Department of Oceanography Deep-Tow Research Group and the Department of Anthropology Nautical Archaeology Program provided logistical support and archaeological expertise. The Minerals Management Service served in a cultural resource management capacity. The United States Navy generously donated the use of *NR-1*, a nuclear powered research submarine, and its associated surface support vessel, *SSV Carolyn Chouest*. Captain Dennis McKelvey, commander of *NR-1*, and his crew, deserve special recognition for their outstanding performance during the Mica shipwreck investigation. Captain Steve Laster, of *SSV Carolyn Chouest* (Edison Chouest Offshore Corporation), and his crew, also deserve credit for their support during the project. The Naval Oceanographic Office provided the project with a MaxRover remotely operated vehicle, and the following three pilots: Jon P. Shepetis, Blaine Korreckt and Guy Lizana. Discovery Channel and Promare also provided financial support for the mission.

Subsequent return visits to the Mica shipwreck site were made possible by other scientific organizations and the offshore service industry. The Sustainable Seas

Expedition, under the direction of Dr. Sylvia Earle, invited the author to accompany them on a biological research cruise. The expedition generously offered to spend several days exploring the Mica shipwreck and retrieving artifacts, using a *DeepRover* manned submersible. Thanks to Doug Weaver, Emma Hickerson and G.P. Schmal, of the Flower Garden Banks National Marine Sanctuary, for their coordination efforts and technical expertise. Sasha LeBaron generously provided his time and knowledge in planning the artifact retrieval system, and attaching it to the manned submersible. Captain Sean T. Stokes, of MSV *Ocean Project*, was an accommodating host during the second expedition.

The author would like to extend his appreciation to Tim Bulman, Dave Medeiros, and Paul McKim, of Deep Marine Technologies Incorporated. They donated four days of ship time aboard the *Rylan T*, as well as the use of a *MaxRover* remotely operated vehicle and a *DeepWorker* manned submersible during the third and final visit to the wreck site.

TABLE OF CONTENTS

	Page
ABSTRACT.....	iii
DEDICATION.....	iv
ACKNOWLEDGMENTS.....	v
TABLE OF CONTENTS.....	viii
LIST OF FIGURES.....	x
CHAPTER	
I INTRODUCTION, DISCOVERY AND RESEARCH PLAN....	1
INTRODUCTION.....	1
VEHICLES AND EQUIPMENT.....	11
INVESTIGATION PRIORITIES.....	20
II THE SITE INVESTIGATION.....	27
III DESCRIPTION OF THE MICA WRECK AND ANALYSIS OF ITS ARTIFACTS.....	49
WOOD SAMPLE ANALYSIS.....	56
METALLIC SHEATHING AND FASTENER ANALYSIS.....	62
LEAD HAWSE PIPE ANALYSIS.....	69
WHAT CAN THE ARTIFACTS TELL US ABOUT THE WRECK?.....	74
IV A BRIEF HISTORY OF METALLIC SHEATHING.....	76
LEAD SHEATHING.....	81
COPPER SHEATHING.....	91
MIXED-METAL SHEATHING.....	98
APPLICATION OF METALLIC SHEATHING.....	108
THE FUTURE OF METALLIC SHEATHING RESEARCH.....	115

CHAPTER		Page
V	THE MICA VESSEL: A HYPOTHETICAL SAILING RIG.....	117
	MASTS.....	126
	SPARS.....	128
	STANDING RIGGING.....	130
	RUNNING RIGGING.....	136
	SAILS.....	139
	CONCLUSION.....	140
VI	CONCLUSIONS.....	141
	THE FUTURE OF DEEPWATER NAUTICAL ARCHAEOLOGICAL RESEARCH.....	143
	WORKS CITED.....	145
	APPENDIX A.....	156
	APPENDIX B.....	181
	APPENDIX C.....	188
	VITA.....	191

LIST OF FIGURES

FIGURE		Page
1	Location of the Mica shipwreck in the Northern Gulf of Mexico.....	6
2	Side scan sonar image of Mica wreck bisected by oil pipeline.....	7
3	Survey route of the Hugin Autonomous Underwater Vehicle.....	9
4	Side scan sonar image of the Mica shipwreck.....	10
5	The United States Navy Submarine <i>NR-1</i> surfaces during the investigation.....	12
6	Control center and internal arrangement on the submarine <i>NR-1</i>	13
7	SSV <i>Carolyn Chouest</i> , the surface support vessel for <i>NR-1</i>	16
8	The Naval Oceanographic Office's <i>MaxRover</i> remotely operated vehicle.....	17
9	The Mica shipwreck investigation artifact lift.....	19
10	Mica shipwreck site grid.....	23
11	Detailed 600 kHz side scan sonar view of the Mica shipwreck.....	29
12	Side scan sonar image of Mica shipwreck.....	31
13	Possible chainplate and deadeye strap on the Mica shipwreck.....	33
14	The keelson bolts on the Mica shipwreck.....	36
15	Bow area of the Mica shipwreck.....	38
16	Starboard bow quarter of the Mica shipwreck.....	41
17	Perspective view of the starboard stern quarter of the Mica shipwreck.....	43
18	The crew of the SSV <i>Carolyn Chouest</i>	45
19	Deep Marine Technology's <i>MaxRover</i> being deployed over the Mica site.....	47

Figure	Page
20	Possible remains of a chainplate or deadeye strap seen aft of amidships on the port side..... 52
21	Site plan drawing of Mica shipwreck..... 53
22	Profile drawing of the Mica shipwreck..... 55
23	Profile view of the port stern quarter of the Mica shipwreck..... 58
24	Photograph of stem and bow of Mica shipwreck..... 59
25	Photograph of starboard stern quarter of Mica shipwreck..... 60
26	A fragment of the copper sheathing retrieved from the Mica shipwreck... 61
27	The refracting electron microprobe sample carrier..... 64
28	Detail of the starboard stern quarter of the Mica shipwreck..... 66
29	Largest fragment of metallic sheathing recovered from the Mica shipwreck..... 67
30	<i>In situ</i> photograph of the starboard lead hawse pipe on the Mica shipwreck..... 70
31	Forward face of lead hawse pipe from the Mica shipwreck..... 71
32	After face of conserved lead hawse pipe from the Mica shipwreck..... 72
33	Interior opening of conserved lead hawse pipe from the Mica shipwreck.... 73
34	Detail of cut marks near the interior opening of the hawse pipe..... 74
35	The false keel from <i>Invincible</i> , lost in 1758..... 93
36	Carpenters applying pine sheathing before the application of metallic sheathing..... 96

Figure		Page
37	A sheathing nail advertisement from 1806.....	112
38	Peter Hedderwick's 1826 rigging plan for <i>Glasgow</i> , a schooner of 151 tons.....	118
39	The gaff rigged schooner <i>Polly</i>	120
40	The two-masted fore-and-aft rigged merchant schooner <i>Hope</i>	121
41	An aging unidentified two-masted topsail schooner.....	122
42	Original builder's plans for the topsail schooner <i>Elizabeth Austen</i>	123
43	Lines of HMS <i>Subtle</i> , lost in a violent squall while pursuing an American privateer in the West Indies in 1812.....	124
44	Hypothetical Mica shipwreck rigging reconstruction.....	125
45	Selected bow area nomenclature	131
46	Lower forward rigging nomenclature.....	133
47	Lower aft rigging nomenclature.....	135
48	Upper forward rigging nomenclature.....	137
49	Upper aft rigging nomenclature.....	138

CHAPTER I

INTRODUCTION, DISCOVERY AND RESEARCH PLAN

INTRODUCTION

The Mica shipwreck was discovered, quite by accident, on 16 February 2001, 65 kilometers (40 miles) southeast of the Mississippi River mouth. The ExxonMobil Corporation had recently laid a 20 centimeter (8 inch) diameter oil and gas pipeline in Mississippi Canyon Lease Block 074 in the Gulf of Mexico. Using a remotely operated vehicle, the oil company performed a routine post-installation inspection of the pipeline. While piloting the craft, the operators noticed an object underneath the pipeline, which they quickly identified as a shipwreck. The pilots decided to explore the wreck site, recording the position coordinates, as well as detailed video footage. The vessel, approximately 19.8 meters (65 feet) in length, sat upright on the seafloor, at a depth of more than 807.7 meters (2650 feet).

Recognizing that the shipwreck might be of historical value, ExxonMobil immediately notified the Minerals Management Service, the federal agency whose duties include managing offshore cultural heritage, including shipwrecks. Dr. Jack Irion, Dr. Richard Anuskiewicz, and David Ball, from the Social Sciences Unit, mobilized on 23 February

This paper follows the style and format standards set forth by the *American Journal of Archaeology*.

2001, and investigated the wreck with the assistance of an Oceaneering Corporation vessel and remotely operated vehicle. The archaeologists from the Minerals Management Service successfully retrieved samples of wood and metal from the vessel, specifically five small pieces of metallic sheathing, several fragments of wood from the outermost layer of planking, and a large lead pipe, along with extensive video documentation. The federal archaeologists made an assessment of the wreck's condition and documented the threats facing it. They estimated that the wooden-hulled, metal-sheathed vessel sank during the first half of the nineteenth century. The federal archaeologists believed that the wreck was of historical significance, and therefore eligible to be entered in the National Register of Historic Places. At this point, the Louisiana State Archaeologist and the Advisory Council on Historic Preservation were advised of the shipwreck and its possible historical significance.

ExxonMobil and the Minerals Management Service discussed management options for the disturbed wreck site. At issue was the proximity of the oil pipeline to the wreck. The pipeline had almost perfectly bisected the vessel across the amidships section, pinning it tightly to the seafloor. As the pipeline was being laid across the sunken vessel, the pressure that the pipeline exerted on the keelson and keel of the ship caused the bow and stern of the vessel to lift approximately one foot above the sediment. This force, however, did not appear to break the structural timbers of the vessel.

The Minerals Management Service and ExxonMobil formulated a management plan that resulted in the minimization of further damage to the Mica shipwreck. Several options were considered. One idea involved placing a large pile of sandbags on either side of the vessel, and then lifting the pipeline and placing it on the sandbags. This procedure would have formed a bridge over the shipwreck, and thus relieved the stress on the keel and keelson. An alternate plan called for cutting and moving the pipeline to another area. Both plans were expensive, and there was a danger that cutting or moving the pipeline, which was under torsional stress, might cause it to whip around, damaging the wreck further. Given the difficulties and expense of working in the deep ocean, as well as the possible danger that moving the pipeline posed to the shipwreck, it was decided that the best management option would be to leave the pipeline where it had originally been laid. The money that ExxonMobil would have spent on moving the pipeline was instead given to the Minerals Management Service, in order to perform a detailed study the wreck. This arrangement was made possible by the Moss-Bennett Act (Executive Order 11593), which allowed collection of money from a private source to apply towards government-sponsored salvage archaeology.

The Minerals Management Service then contacted Texas A&M University about entering in a joint partnership to investigate the newly found wreck. Scientists from the Department of Oceanography and archaeologists from the Nautical Archaeology Program in the Department of Anthropology worked together to draft a cooperative agreement with the Minerals Management Service. The joint proposal called for the

investigation and possible partial excavation of the Mica shipwreck. The proposal recommended the use of several sophisticated research tools designed specifically for use in the deep ocean, including the United States Navy's nuclear-powered research submarine, *NR-1*, as well as Texas A&M University's Deep-Tow underwater remote sensing system. The plan also called for the use of several remotely operated vehicles, tasked specifically with photographing and retrieving selected artifacts. The proposal was reviewed and accepted by the Minerals Management Service, and the Texas A&M University Research Foundation, which administered the accounts related to the Mica wreck excavation. With approval and funding in hand, it was now time to consider how to investigate and excavate the shipwreck.

Nearly all of the shipwrecks studied by nautical archaeologists have been accessible by trained S.C.U.B.A. (Self-Contained Underwater Breathing Apparatus) divers. The extreme depth of the Mica shipwreck made the use of traditional S.C.U.B.A. diving equipment impossible. The depth necessitated the use of both manned and unmanned machines that were capable of withstanding the 8240 kilopascals (1200 pounds of pressure per square inch) that the water column exerted around the shipwreck. However, extreme pressure was not the only problem facing the scientists. Sunlight dissipated or reflected long before it reached the seafloor, shrouding the vessel in eternal darkness. Ample artificial illumination was required to perform any task.

The location of the shipwreck also proved less than ideal. It was situated on a bed of fine silt that was continuously discharged from the Mississippi River into the Gulf of Mexico (Figure 1). Particles of sediment constantly rained down on the wreck, which decreased visibility. While working inside or around the vessel, the sediment that had already been deposited on the wreck was easily disturbed, and could remain suspended for several minutes. The omnipresent currents proved a double-edged sword. They could swiftly flush out the disturbed sediments, but they made maneuvering and holding position difficult. The deep ocean currents also dictated the search patterns and excavation areas, as it was difficult, if not impossible, to hold a large submarine or vehicle cross-wise in a current. While the current direction was variable, it was usually under half a knot.

A unique hazard of working in the Mica shipwreck area was the location of the oil and gas pipeline. The pipeline almost perfectly bisected the wreck near amidships. As it was being laid, the pipeline contacted the remains of the vessel, knocking down the sides of the hull in the amidships section (Figure 2). The pipeline came to rest on the keelson. It was evident that the structural integrity of the Mica vessel remained, as the force of the pipeline on the keelson and keel caused the bow and stern to lift slightly out of the sediment. The pipeline served as a sort of fence, dividing the wreck into north and south halves. The submarine *NR-1*, with its ability to land and drive on the seafloor, was restricted in its operational movement because of this obstacle.

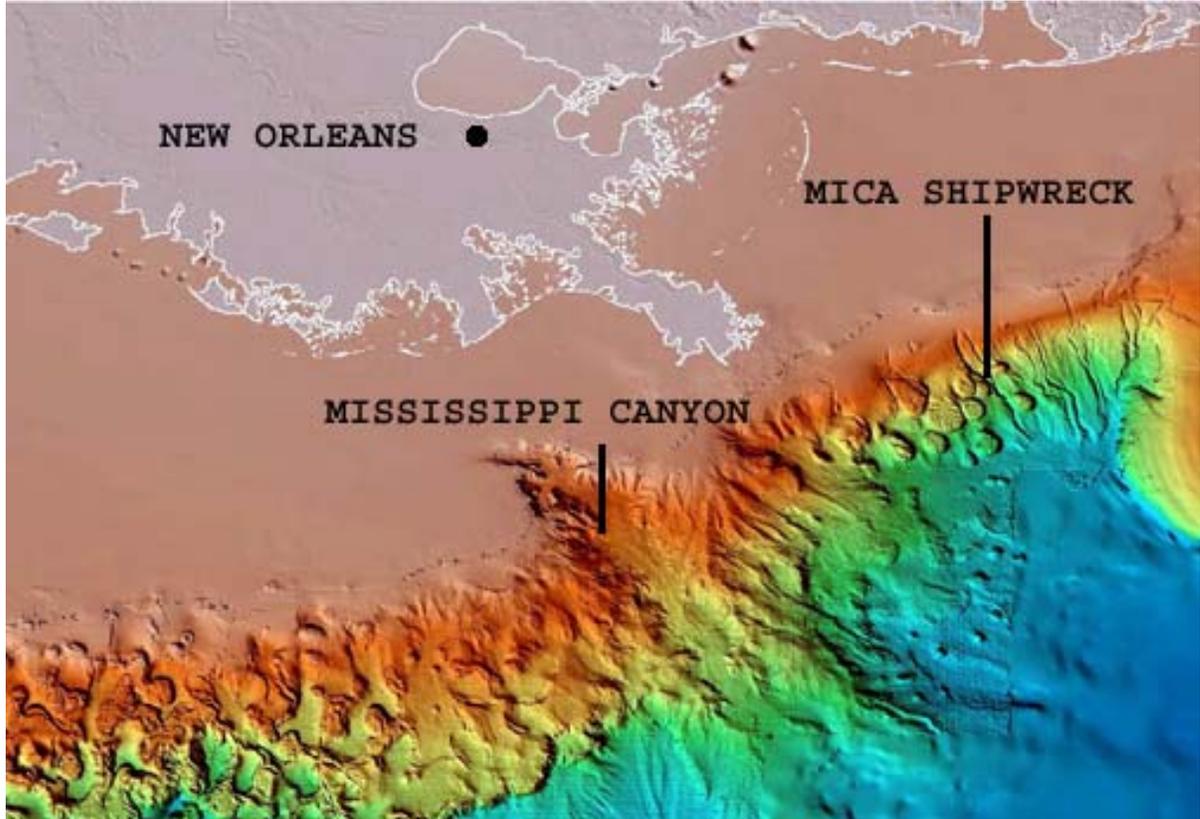


Figure 1. Location of the Mica shipwreck in the Northern Gulf of Mexico (Map courtesy of William R. Bryant and Jia Y. Liu, Texas A&M University).

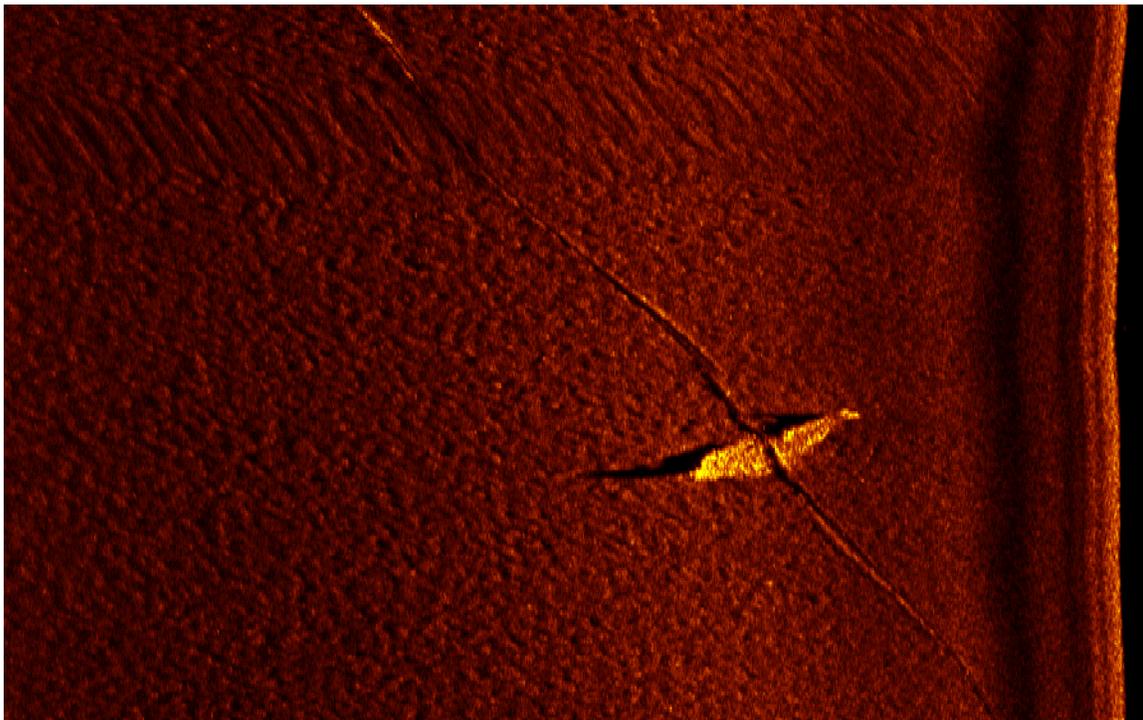


Figure 2. Side scan sonar image of Mica wreck bisected by oil pipeline (Image courtesy of the United States Navy).

Another major challenge of working in the deep ocean that rarely confronts land archaeologists relates to the spatial location of the site. There is, as of yet, no underwater global positioning system. Knowing the coordinates of a wreck will only get you over the site. It is another matter to descend through thousands of feet of black water and relocate the target object. Finding and maintaining position underwater requires extensive planning, training, and foresight. Methods of determining accurate position underwater include dead reckoning, gyroscopic navigation, surface tracking, Doppler-baseline position determination, and tracking of natural or manmade subsea landmarks. Dead reckoning requires that the navigator constantly monitor the speed and heading of

a vehicle in a three dimensional environment and relate this to a fixed point of reference. This method can become inaccurate or exceedingly complicated when the navigator fails to correctly account for currents and angles of ascent and descent. Gyroscopic navigation depends on inertial forces acting upon a gyroscope. These movements are collected and analyzed by a computer. This method generally provides accurate underwater positioning that can be communicated to surface vessels via tether or acoustic modem. Underwater vehicles can be tracked by surface ships using remote sensing systems. This method is subject to error caused by distortion of signals through the water column. New developments in Doppler positioning technology allow submerged vehicles to determine their position relative to a pre-positioned baseline. The positions of underwater vehicles can also be checked against known bathymetric landmarks, however, there are large areas of the seafloor that are almost totally featureless. The Mica wreck had the advantage of being crossed by a pipeline. Once the pipeline was located, it was a simple task of following it in the right direction until the shipwreck was detected.

While archaeologists planned the excavation, C&C Technologies of Lafayette, Louisiana performed a survey of the shipwreck area using an autonomous underwater vehicle. The torpedo-shaped untethered robot flew back and forth over the wreck at regular width intervals and at a preset altitude (Figure 3). The goal of the survey was to define the extent of the wreckage and detect any geohazards that might complicate the investigation (Figure 4).

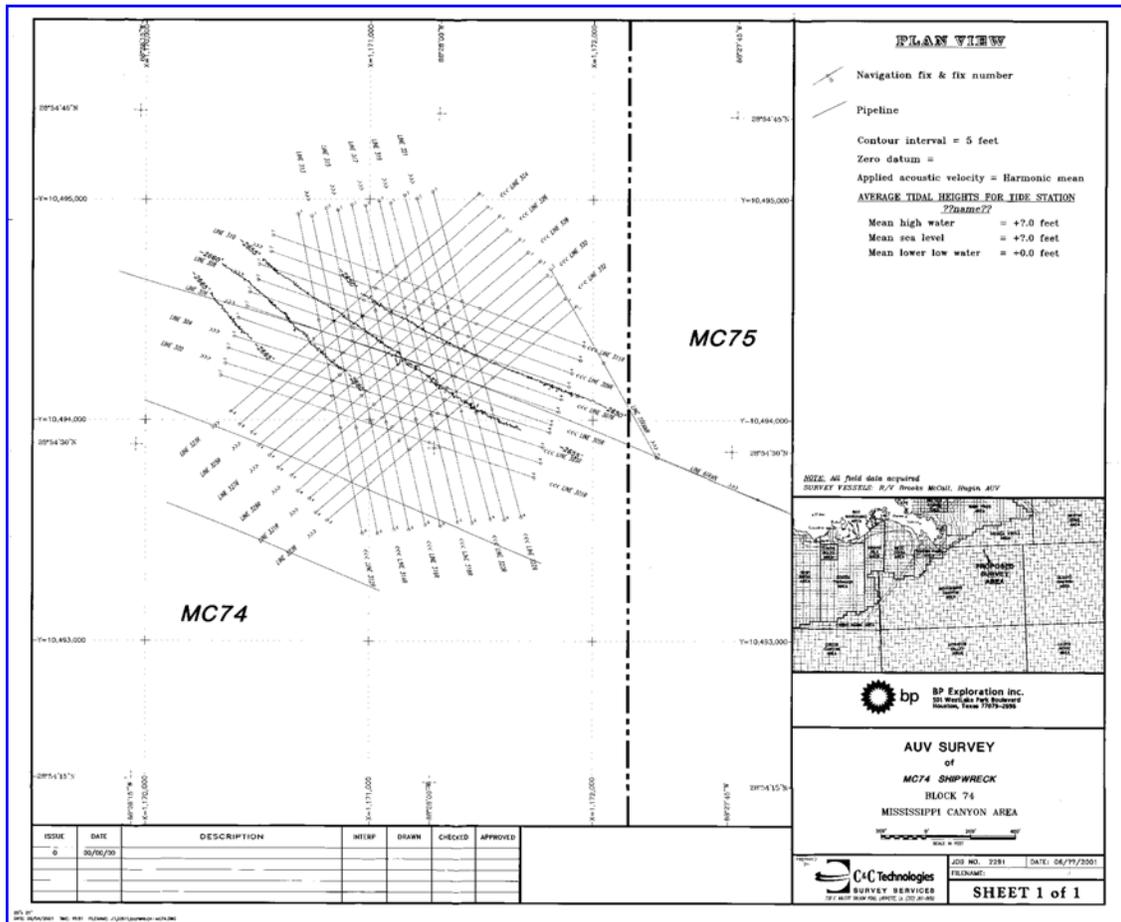


Figure 3. Survey route of the Hugin Autonomous Underwater Vehicle. The robot was equipped with multi-beam and side scan sonar systems (Image courtesy of C&C Technologies).

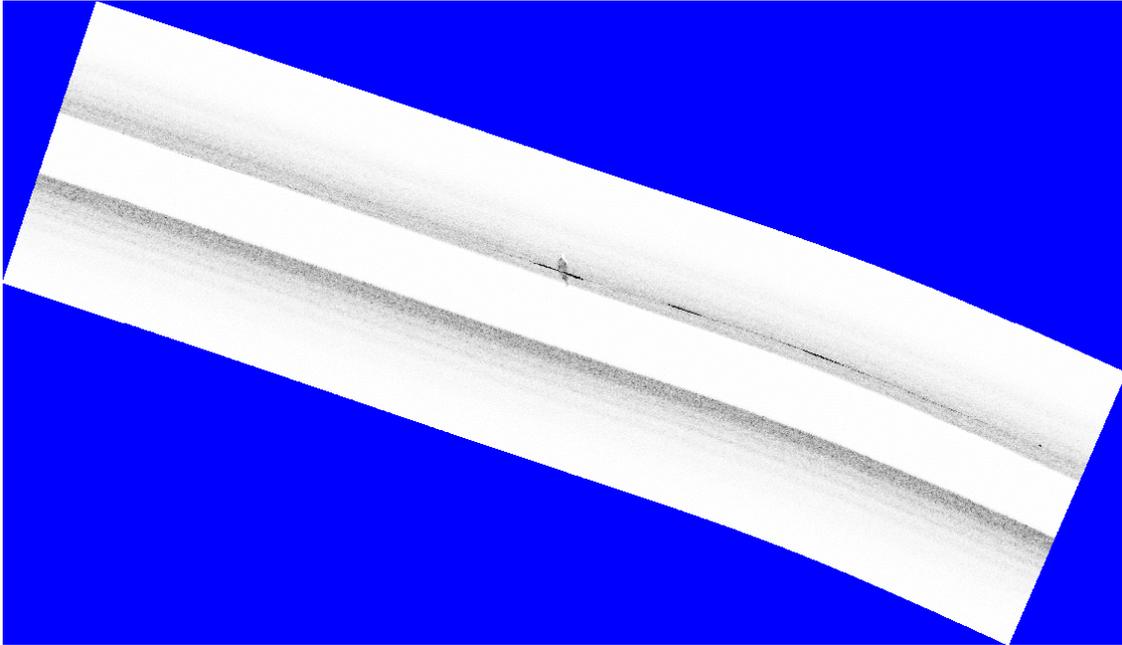


Figure 4. Side scan sonar image of the Mica shipwreck. Note the pipeline running from top left to lower right (Image courtesy of C&C Technologies).

Working in the deep ocean requires extensive planning, equipment selection and preparation. The amount and variety of archaeologically oriented tasks that could be performed underwater were necessarily dictated by the capabilities and payloads of the vehicles. Each major piece of equipment will be discussed below, with specific references to its capabilities and limitations. The end of the section will also discuss the use and modification of equipment and include a description of an ideal platform from which to perform deepwater archaeological research.

VEHICLES AND EQUIPMENT

The nuclear powered submarine *NR-1* was designed, built, and operated by the United States Navy (Figure 5). The 45.72 meter (150 foot) submarine was launched in 1969 and was capable of diving to 914.4 meters (3000 feet). It has numerous unique features that made it a valuable asset to marine archaeologists and other scientists. The submarine is crewed by 12 men, including the captain, executive officer, and chief engineer. The sailors are divided into two watches consisting of six men each. This configuration allows one rider or scientist to accompany the submarine during diving operations. The rider typically sits immediately behind the pilot and navigator of the submarine, which allows for immediate and effective communication (Figure 6). *NR-1* is capable of remaining submerged for months, with the only limiting factors being food and crew morale.



Figure 5. The United States Navy Submarine *NR-1* surfaces during the investigation (Photograph by author).



Figure 6. Control center and internal arrangement on the submarine *NR-1* (Photograph by author).

The submarine has several unique features, the most prominent of which are wheels that allow the vessel to drive on the seafloor. The maneuverability and agility of *NR-1* proved invaluable. The submarine is also equipped with a large manipulator arm and 14 digital video cameras that have zoom, pan and tilt features. Numerous lights are attached to the hull of the submarine, providing ample illumination in the otherwise pitch-black environment. There is a work module attached to the external hull of the submarine, located immediately in front of the manipulator arm, which contains various tools. These tools are used by the manipulator arm, and included soil coring devices as well as gripping and cutting devices. There are three view ports on the lower bow surface of the hull, directly behind the manipulator arm. From this vantage point it is possible to observe the actions of the manipulator arm as well as search the wreck site without the use of cameras. The submarine can communicate with vessels on the surface via radio and through-water acoustical modem.

NR-1 is powered by a small nuclear reactor that drove a turbo-alternator, which delivered electricity to two external electric motors with shrouded propellers. For precise maneuvering, the submarine is equipped with two forward and two aft thrusters. These thrusters are diagonally opposed and reversible, which allows for nimble and precise control of the vehicle's position. The thrusters can also be used as a sort of water jet, by directing the column of exhaust water towards areas of the worksite that need to be dusted off. The submarine cost approximately \$1,000,000 per week in maintenance and

operating expenditures, while its tender, the *SSV Carolyn Chouest*, cost approximately \$35,000 per day.

SSV Carolyn Chouest is the surface support vessel for *NR-1* (Figure 7). The 72.5 meter (238 foot) vessel has a beam of 15.9 meters (52 feet) and a draft of 5.2 meters (17 feet). It had a total displacement of 1599 long tons. The surface vessel tows *NR-1* between work areas, as well as serving as a floating supply warehouse and providing quarters for the extra crewmembers. During the Mica shipwreck investigation, the scientists were housed in staterooms on the *SSV Carolyn Chouest*.

Besides providing the archaeologists and scientists with a presence at the wreck site, *NR-1* served as a platform for conducting explorations of the shipwreck with a SeaBotix *Little Benthic Vehicle* 1500 remotely operated vehicle. This small robot is housed in a garage on the upper hull surface of the submarine. The garage is designed to securely hold the vehicle during diving operations, as well as a tether management system. The robot is operated from inside of the submarine. It is capable of high-resolution photography and digital video recording, and is equipped with a small manipulator arm. The vehicle is highly maneuverable, and rated for work to a depth of 1500 meters (4605.7 feet). However, problems with the underwater electrical connectors prevented this piece of equipment from being successfully deployed at the archaeological site.



Figure 7. SSV *Carolyn Chouest*, the surface support vessel for *NR-1*. The vessel was docked at Pensacola Naval Air Station, Pensacola, Florida (Photograph by author).

In order to remove the overburden inside the wreck and retrieve larger artifacts, a work-class remotely operated vehicle was utilized. The Naval Oceanographic Office provided a Deep Sea Systems *MaxRover* work system, accompanied by three pilots (Figure 8). The large unmanned vehicle is controlled via a fiber optic tether, which is capable of sending real-time high-resolution digital imagery to the surface. The robot is equipped with a manipulator arm and six thrusters, which allow the vehicle to hold station with remarkable precision.



Figure 8. The Naval Oceanographic Office's *MaxRover* remotely operated vehicle. Here it is seen preparing to explore the Mica shipwreck site (Photograph by author).

An artifact retrieval system was designed and built at the Offshore Technology Research Center at Texas A&M University (Figure 9). The system consisted of a square steel mesh-lined box containing ten individually numbered barrels with doors that prevented retrieved material from escaping. The box also contained an open area in the center, which was designed to hold large pieces of the vessel's metallic sheathing, or structural samples of the vessel, including the sternpost. This open area was also useful for carrying tools down to the site, including four one-meter (3.3 foot) scale bars. These scale bars were built like sawhorses, to allow them to sit on top of the unconsolidated sediment, both inside and around the shipwreck.

The artifact retrieval system is designed to be deployed and retrieved by a winch on the SSV *Carolyn Chouest*. When deployed on the seafloor, the artifact retrieval system serves a secondary purpose as a clump weight to which the *MaxRover* tether is attached. The basket was positioned approximately 50 meters (164.1 feet) from the wreck. This position allows both the *MaxRover* and the SeaBotix *Little Benthic Vehicle 1500* to access the artifact retrieval system. Subsequent expeditions to the Mica wreck site used similar, albeit smaller, versions of the artifact retrieval system.

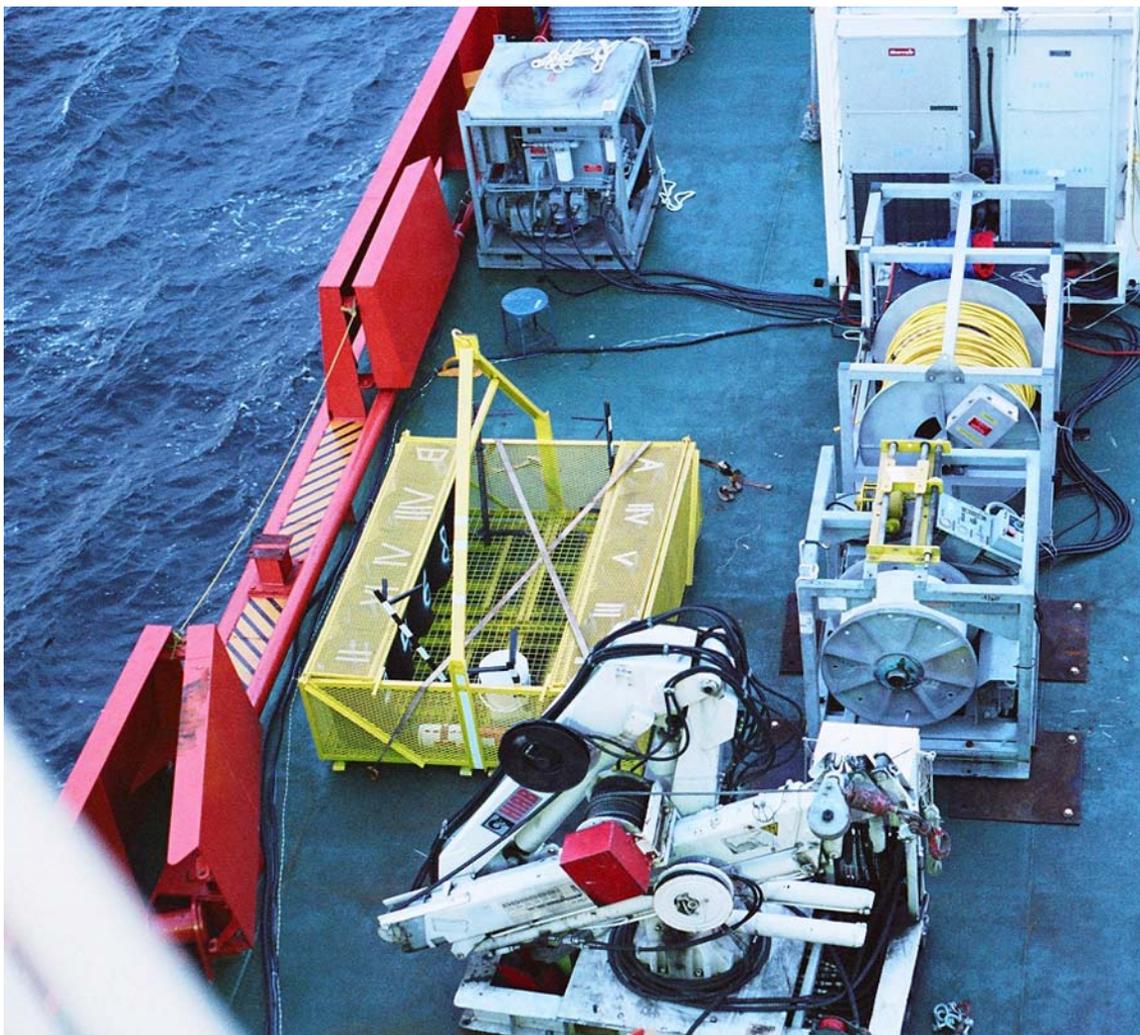


Figure 9. The Mica shipwreck investigation artifact lift. The lift, visible in the center of the photograph, was designed to securely carry artifacts from the wreck site to the surface vessel. The basket also served as a clump weight for the MaxRover vehicle (Photograph by author).

Several additional tool systems were also considered, including a water dredge and an air lift for removing overburden, as well as shrouded propellers designed to create currents that would fan the suspended sediment away from the work area. The remotely operated vehicle employed by the investigators was not capable of powering a water dredge. There was also no supply of compressed air available at the extreme depths with which to operate an airlift. As a result, the research vehicles had to wait for several minutes for the suspended overburden to settle each time the work area was disturbed.

INVESTIGATION PRIORITIES

During the planning stages of the project, the nautical archaeologists and oceanographers identified several excavation priorities. These tasks were ordered by complexity and priority and then reworked according to the capabilities and schedules of the equipment operators. It was decided that after the wreck was located, the first order of business would be to make an extensive photographic and side scan sonar record of the vessel's condition and record the placement of visible artifacts, before the site was disturbed. It was necessary to determine the exact orientation of the pipeline to the wreck, as this would dictate how the undersea vehicles could approach the site, without damaging the shipwreck or the pipeline. After thoroughly imaging the wreck, the next step would be to identify and retrieve diagnostic artifacts, along with structural wood and metallic sheathing samples. An extensive video log would be kept, in order to have a document

with which to compare the near continuous video footage taken by the submarine's numerous cameras. Artifact selection would be based on the pre-excavation site plan.

In addition to artifacts, the submarine was equipped to take sediment core samples. The sediment cores would be retrieved from in and around the wreck. The sediment samples would be stabilized for future pollen analysis and a comparison of the stratigraphy of the deposited sediments in and around the wreck. Obtaining sediment samples containing pollen was a priority because they could provide evidence of a perishable cargo that had long since dissolved. Only the durable pollen grains that had become trapped in the sediment could provide clues as to the possible nature of the ship's cargo. The sediment cores would also be taken some distance from the wreck to provide control samples in order to eliminate background contamination.

To aid in the organized recovery of artifacts for conservation and analysis, a site grid was developed that divided the interior of the wreck into eight sections containing four quadrants each (Figure 10). The shipwreck site was divided into port and starboard halves along the keel. Each half was divided into four sections that were five meters (16.4 feet) square. Each five meter (16.4 foot) square section would be further subdivided into quadrants measuring 2.5 meters (8.2 feet) on a side. A system of numbering the artifacts and entering them into a catalog upon retrieval was formulated. The remotely operated vehicle pilots would place retrieved artifacts in individually numbered containers on the artifact retrieval system. The entire process of artifact

retrieval and deposition of the objects in the artifact retrieval system would be recorded by cameras on the remotely operated vehicles, and noted by archaeologists watching the excavation via live video feed on the surface ship. The site grid could be superimposed on the plan view mosaic created during the submarine flyovers. When the artifact retrieval system was raised to the deck of the SSV *Carolyn Chouest*, the artifacts would then be immediately labeled and immersed in storage tanks filled with saltwater. The tanks would be covered to protect the artifacts from sunlight.

After the removal of selected diagnostic artifacts on the surface of the wreck site, the team would then prepare to remove sediment in the bow and stern areas of the shipwreck. The submarine and remotely operated vehicle would again image the entire site. The idea was to have multiple plan view mosaics of the entire work area taken as each layer of sediment and artifacts were removed.

Each transect of the submarine would cover approximately five meters (16.4 feet), with the cameras on the submarine being five meters (16.4 feet) above the sea floor. It was estimated that the wreck site could be thoroughly imaged by piloting the submarine over the wreck three times on the longitudinal axis, and five times across the transverse axis. The spacing and redundancy of imaging in two directions would provide over 200 percent overlap in image coverage.

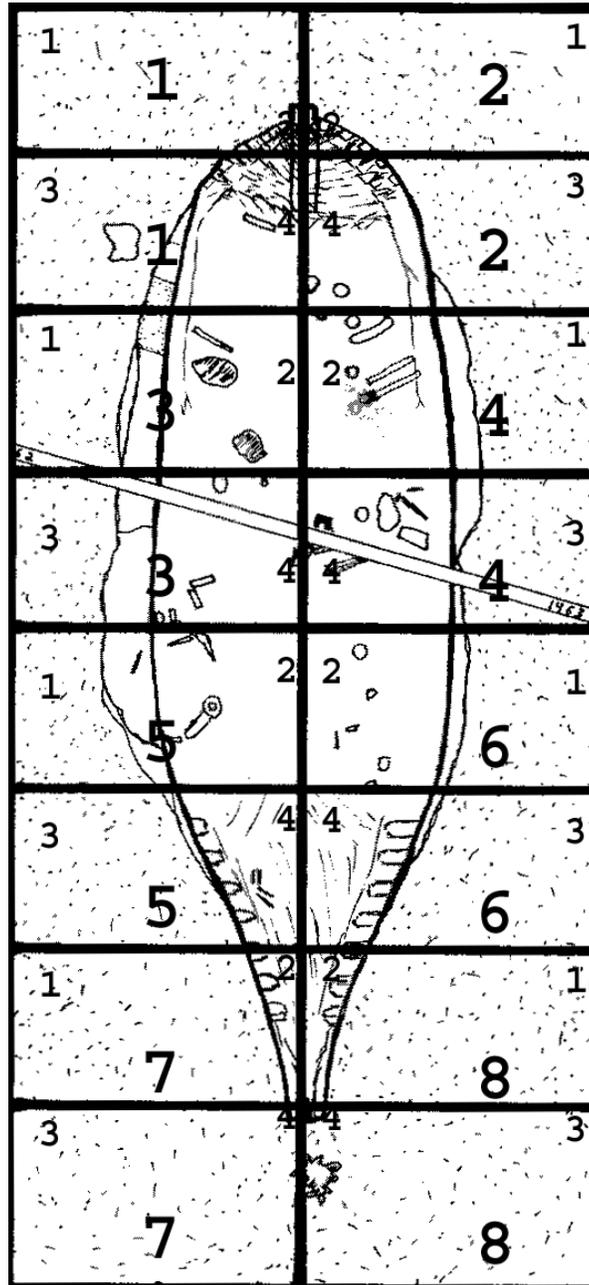


Figure 10. Mica shipwreck site grid. The site grid shows quadrants (bold numbers) and sections (smaller numbers). Even number quadrants represent areas inside of the hull, while odd number quadrants represent areas outside the hull (Drawing by author).

After the second plan view photo mosaic had been completed, the archaeologists would concentrate on removing overburden in the bow and stern areas, and retrieving select diagnostic artifacts. The sediment would be removed by careful application of the maneuvering thrusters on *NR-1*. As time allowed, the process of removing artifacts and sediment layer by layer would continue until all of the overburden had been removed, exposing any extant framework of the vessel. The archaeologist on board the submarine would also draw or sketch objects seen in and around the wreck site.

Once the investigators cleared away enough of the sediment to expose the structural timbers of the ship, they would retrieve wood samples of the keelson, keel, frames, posts, mast steps, and planking, using the manipulator arms on the *MaxRover* and *NR-1*. These wood samples would be placed in separate compartments on the artifact retrieval system. The archaeologists planned to have the wood samples identified and, if possible, submit them for dendrochronological analysis.

The external starboard aft quarter of the vessel appeared well preserved, with intact metallic sheathing still covering the hull planking. The archaeologists believed that the sheathing was a highly diagnostic artifact, and that removing a full sheet, measuring 0.35 by 1.22 meters (1.2 by 4 feet) could provide clues to the origin of the vessel.

It was determined that raising the entire vessel would be difficult and expensive. The archaeological team believed, however, that carefully removing the top section of the

sternpost might yield information about the vessel's construction, and more importantly, permit the recovery of one of two gudgeons still attached to the to the post. The plan was to remove only the upper gudgeon, to minimize the disturbance to the wreck's stern.

After thoroughly excavating the wreck, the excavation priority plan called for surveying a one kilometer box centered on the wreck site. The goal of this endeavor was to locate a debris trail and possibly the missing rudder. The survey would utilize the high resolution side scan sonar, sub bottom profiler, and video cameras on the submarine.

In addition to this visual survey, we believed that digging a series of test pits around the wreck site might reveal additional diagnostic artifacts. A grid measuring 50 meters (164.1 feet) on a side would be laid out, with holes being dug by the remotely operated vehicle every 10 meters (32.9 feet), beginning with those intersections closest to the wreck, and working outward as time permitted. The remotely operated vehicle would use a water jet with a nozzle situated on the manipulator arm to fan away sediment to a depth of half a meter (1.6 feet). A camera positioned near the end of the manipulator arm would allow scientists and the vehicle pilots to closely observe the site as the sediment was removed.

The archaeologists planned to research historical records that identified types of sailing vessels common in the Gulf of Mexico during the nineteenth century. Patterns of trade and navigation would also be analyzed for clues relating to the career and demise of the

Mica shipwreck. Ship enrollment records from New Orleans would be scrutinized in an effort to create 1) a list of known vessel losses in the area, and 2) a database of ships fitting the general physical parameters found on the Mica shipwreck.

A significant part of the strategy for studying the wreck was to determine the level of technology it contained. A detailed analysis of the hull's components, especially the metallic sheathing, could help identify the type, rig, nationality, and period of the vessel. Documenting artifacts in and around the shipwreck, it was hoped, might offer clues to the vessel's origin, crew, and its destination.

CHAPTER II

THE SITE INVESTIGATION

After months of planning and preparation, the Mica wreck field investigation took place in July 2004. The SSV *Carolyn Chouest* and *NR-1* were docked in Pensacola, Florida on 11 July 2002. This was the only opportunity that the archaeological crew had to load large items of equipment and supplies, including the remotely operated vehicle, tether management system, control van, and artifact retrieval system. The remotely operated vehicle system and the artifact retrieval system were brought to the pier on trailers and loaded onto the back deck of the SSV *Carolyn Chouest* with a large crane. The team spent the next three days securing the equipment to the deck, and preparing and testing the remotely operated vehicles. Everything was in order for the excavation to begin ten days later.

At 0530 on 24 July 2002, the archaeological investigation team, along with the remotely operated vehicle pilots and a camera team from Discovery Channel, boarded a motor yacht that took them from Biloxi, Mississippi to a rendezvous point with the SSV *Carolyn Chouest* in the Gulf of Mexico, approximately 65 kilometers (40 miles) south of the Mississippi River mouth.¹ After making contact with the naval vessels, the scientific

¹ The following section was largely taken from submarine dive logs kept by the archaeologists during the expedition. Copies of the dive logs are attached in Appendix A. Time denotations follow the standard 24 hour military clock. For example, 0930 equals 9:30 a.m., while 2342 is equivalent to 11:42 p.m.

crew was transferred to the SSV *Carolyn Chouest*, while the author was transferred via a rigid hulled inflatable boat to the surfaced *NR-1*. After installing the SeaBotix *Little Benthic Vehicle* 1500, the submarine prepared to dive. At that time, underwater electrical connector problems with the small robot prevented it from being deployed from *NR-1*.

The descent to the wreck area took one hour. The side scan sonar system and the obstacle avoidance sonar (forward looking sonar system) detected three parallel pipelines and the Mica shipwreck at 1517 on 24 July 2002. The navigator on *NR-1* plotted a grid for obtaining plan view digital video images and side scan sonar images of the wreck. According to the depth gauge on the submarine, the wreck was lying on the seafloor at a depth of 810.4 meters (2660 feet). Measurements taken by the obstacle avoidance sonar system showed the wreck to have an overall length of 20.4 meters (67 feet). High resolution 600 kHz side scan sonar images of the wreck site were collected from an altitude of 4.6 meters (15 feet) above the seafloor (Figure 11). These images clearly show the pipeline, shipwreck, and some scattered debris. The side scan sonar imaging was completed at 1625 on 24 July 2002.

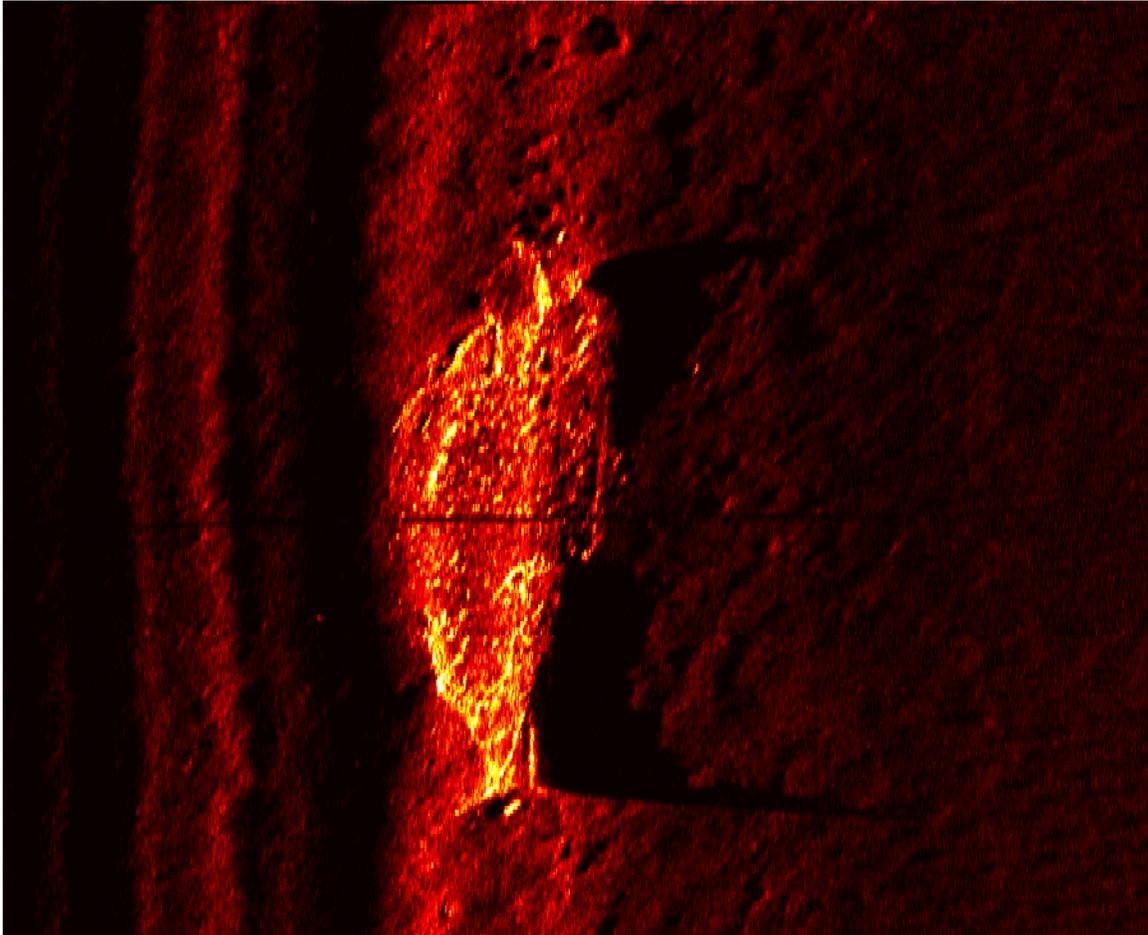


Figure 11. Detailed 600 kHz side scan sonar view of the Mica shipwreck. The stern profile can be seen in the acoustic shadow in the bottom right of the photograph (Image courtesy of the United States Navy).

NR-1 then moved into position to take plan view digital video imagery from an altitude of 4.6 meters (15 feet). However, after receiving word of from the surface that the *MaxRover* was having mechanical problems, it was decided that *NR-1* should attempt to collect sediment cores from in and around the wreck. At 1636 on 24 July 2002, the captain of *NR-1* bottomed the boat and began to drive the submarine at 0.54 kilometers

per hour (1/3 of a knot) along the seafloor. The submarine identified the wreck on the video monitor and slowly came to a stop, with the bow of the submarine protruding over the starboard stern quarter. However, a failure in the external hydraulic system resulted in the inability of the manipulator arm to grasp and operate the sediment coring devices, which were housed in the work module situated below the bow of the submarine. The crew then decided to collect detailed digital images of certain aspects of the wreck. The submarine spent the next several hours approaching the wreck from different quarters. The submarine would touch down on the seabed several hundred meters from the wreck and drive along the seafloor until the wreck could be seen (Figure 12). *NR-1* slowly approached the wreck until the bow video cameras and view ports provided the best opportunity to visually explore the wreck. Detailed images were taken of the metallic sheathing, piles of metallic nails, ceramic and glass shards, and the visible structure of the wreck.

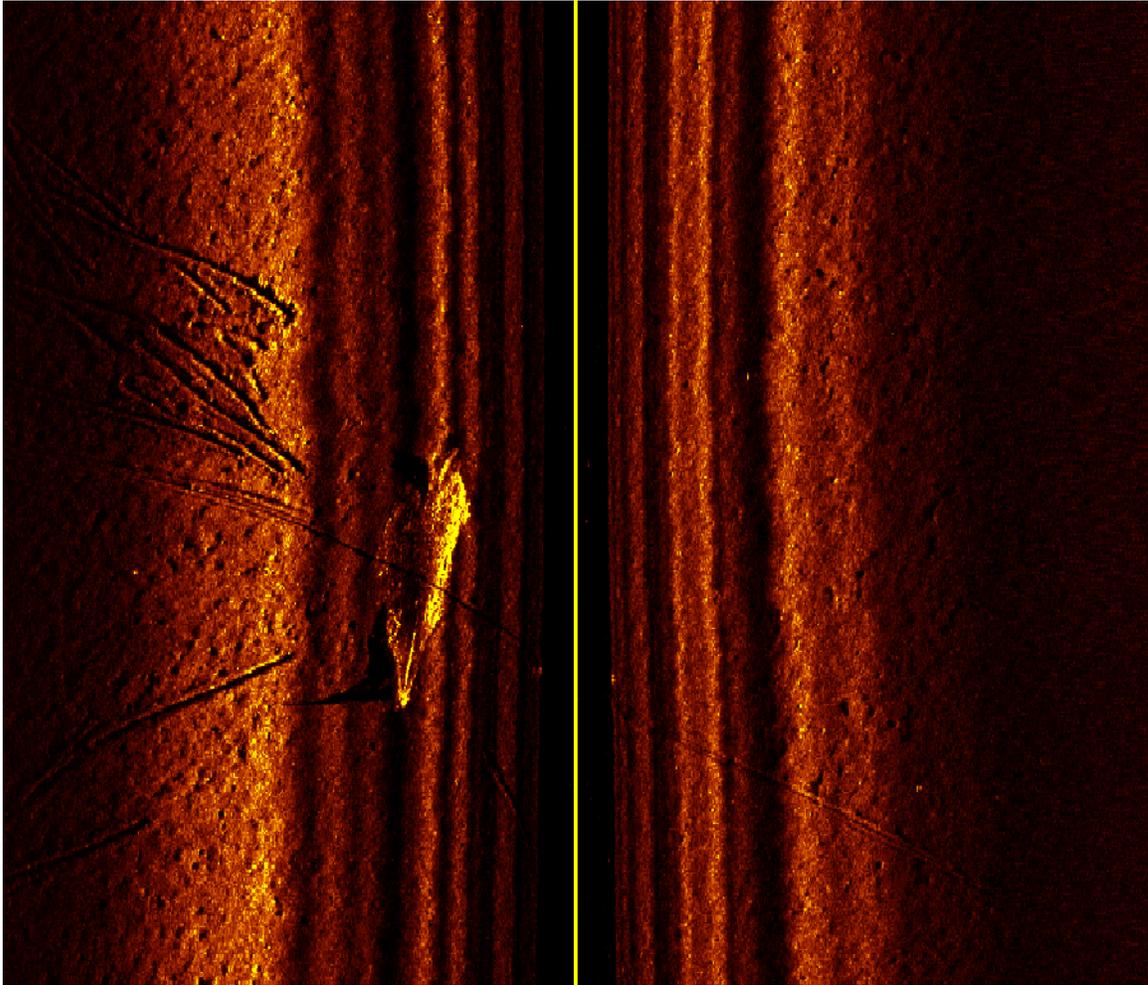


Figure 12. Side scan sonar image of Mica shipwreck. Note the numerous tire tracks (left) where the submarine drove along the seafloor. The ruts made maneuvering on the seafloor more difficult as the investigation continued (Image courtesy of the United States Navy).

After completing the first detailed profile footage of the shipwreck, the submarine ascended to a height of 4.6 meters (15 feet) to take plan view digital images of the wreck site. A total of five passes along the North-South axis were recorded, but suspended particles that scattered and reflected the powerful lights on the submarine resulted in low resolution footage that lacked detail. After completing the video transects, *NR-1* began to

search the area around the wreck. Using an expanding box search pattern, with the shipwreck at the center, the submarine methodically explored the seafloor around the shipwreck. The archaeologists utilized high resolution side scan sonar and video photography to conduct the search. They hoped to find the remains of the rudder or masts that had likely broken away from the ship as it descended through the water column. The search yielded two hits, however, upon further investigation both objects appeared to be bundles of recently discarded rubbish.

After investigating the targets, the archaeologists decided to obtain more plan view footage of the shipwreck, this time from a lower altitude. The variable velocities and direction of currents made maneuvering the submarine difficult, but the crew was able to make several passes at an altitude of 3.1 meters (10 feet). Visibility had improved considerably since the first attempt, owing to fewer suspended particles in the water surrounding the wreck. After this task was completed, the submarine settled on the seafloor and began driving towards the northeast corner of the wreck. *NR-1* took close up digital video images of possible rigging elements, including deadeyes and chainplates (Figure 13). With the view ports on the underside of the submarine's bow, it was possible to view the wreck directly, without the use of cameras. While the view ports provided a good view of the wreck, it was not possible to take high-quality still photographs through the thick glass. The first dive lasted over 21 hours. Upon surfacing, the archaeologists and naval personnel discussed the results of the first dive, the condition of the equipment and how this affected the excavation priorities.



Figure 13. Possible chainplate and deadeye strap on the Mica shipwreck (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

On the surface, technicians set about repairing the manipulator arm on *NR-1*, while the *MaxRover* pilots finished repairs on the large remotely operated vehicle. After briefing the surface crew about the events of the first dive, it was decided that the submarine would dive again and work in concert with the now-functional *MaxRover*, retrieving artifacts from the wreck, and depositing them in the artifact retrieval system. The author was then transferred to *NR-1* and the submarine began its second dive of the expedition at 1210 on 25 July 2002. Through precise navigation and control of the vessel, the submarine was able to land on the seafloor in one of its previously made tire tracks. The submarine followed this track until it once again located the shipwreck. As work on the

site was about to begin, the submarine received word that the *MaxRover* had been destroyed in an accident on the surface. The submarine immediately ascended to the surface where naval personnel and archaeologists could assess the situation.

At 1500 on 25 July 2002, the *MaxRover* was undergoing a systems check test on the surface, when control over the vehicle was lost due to a failure of the fiber-optic cable splice. Unfortunately, SSV *Carolyn Chouest's* dynamic position system was active at the time of the systems check. This system, controlled by a computer connected to the engines and thrusters, allows a vessel to remain within several meters of a set of preprogrammed coordinates of a vessel. The tether of the remotely operated vehicle became fouled in *Chouest's* starboard propeller, when it violently smashed the *MaxRover* against the underside of the hull. The tether soon parted and the remotely operated vehicle was then sucked into the port propeller, where it was destroyed. The entire event, from the loss of telemetry to the crushing of *MaxRover*, occurred in less than a minute. Several pieces of syntactic foam were eventually recovered, but the bulk of the machine was pulverized and lost, and both of SSV *Carolyn Chouest's* propellers were fouled. Navy divers eventually cleared the tether from the starboard propeller, but it took several days to dislodge the debris from the port propeller.

The loss of *MaxRover* made it necessary to reorder the priorities of the Mica wreck investigation. It was no longer possible to recover small objects from the wreck (*NR-1's* manipulator arm proved too clumsy for all but large items). Building on the successes of

the first two *NR-1* dives, the archaeologists decided to use the submarine's capabilities to closely inspect and record the wreck visually, and possibly recover larger objects for conservation, analysis and dating. During the extended surface interval to clear SSV *Carolyn Chouest's* propellers, the archaeological team came up with a set of revised investigation priorities:

1. Place a reference scale inside of the hull, and mosaic the entire area as slowly as possible.
2. Make a detailed inspection of the starboard bow quadrant, looking for evidence of dead eye straps and chainplates.
3. Look for evidence of: mast steps, a pump box or tube, the type of ballast, and sacrificial planking.
4. Take sediment cores for pollen grain analysis.
5. Retrieve the upper end of the sternpost along with its associated metallic sheathing, and gudgeon. Earlier inspection of the stern showed that a portion of the post was eaten away below the upper gudgeon, and that it should be possible to separate the top for recovery by the manipulator arm on *NR-1*.
The archaeologists knew that copper alloy gudgeons often had maker's marks or other identifying features that indicated origin and date of manufacture.
6. Assess stability and condition of the wreck and associated small friable artifacts.
7. Make a final photographic mosaic of the entire wreck site.

With the SSV *Carolyn Chouest* and *NR-1* again fully operational, the archaeologists resumed their investigation of the Mica shipwreck. Dr. Rik Anuskiewicz, the second scientist to ride on the submarine, commenced his dive at 1820 on 26 July 2002. A measuring bar, left behind during an earlier visit by a remotely operated vehicle, was leaning against the pipeline approximately 30.4 meters (100 feet) west of the wreck area. Dr. Anuskiewicz directed the crew of the *NR-1* to pick up the measuring bar and place it abaft of the pipeline, near the row of keelson bolts (Figure 14).

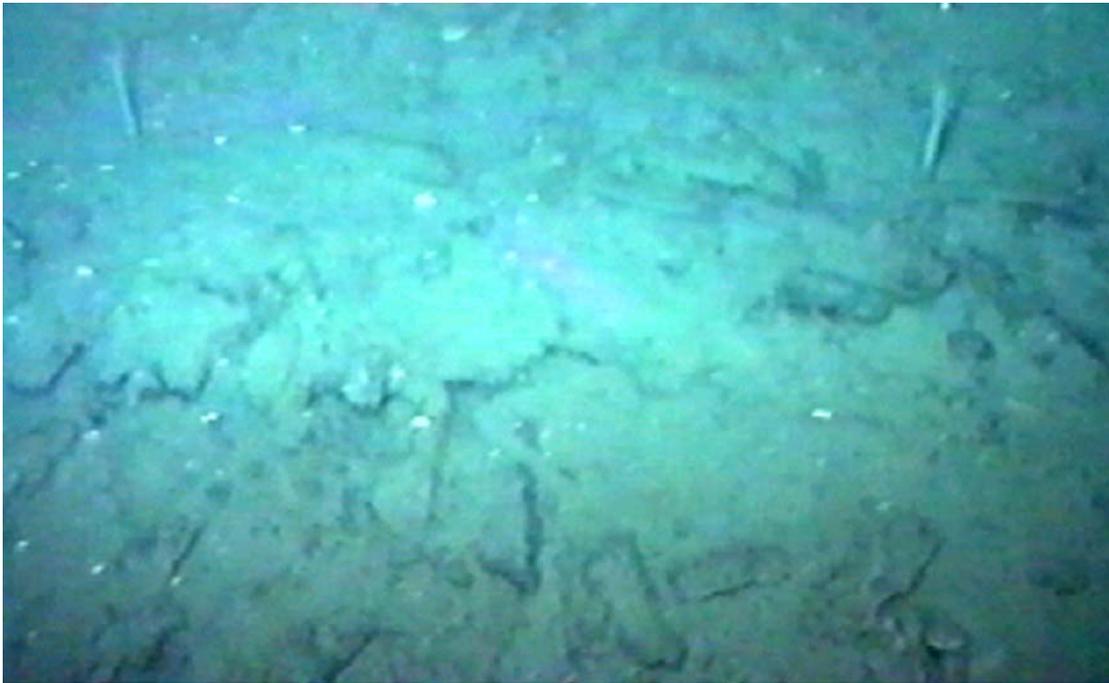


Figure 14. The keelson bolts on the Mica shipwreck. They do not appear corroded, leading to the assumption that they were made of a copper alloy, not iron (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

Once the reference scale was in place it was time to image the site, but strong bottom currents made it impossible for the submarine to hold its position or land in the starboard bow quadrant. The submarine was instead maneuvered into the port stern quadrant, where Dr. Anuskiewicz attempted to dust off loose sediment using the submarine's maneuvering thrusters. He also had the submarine's manipulator arm technician nudge or pick up several small metallic artifacts as part of a test to see if the arm could be used to retrieve small finds. In the deep ocean, the iron objects did not form the thick protective concretion layer normally found in shallower sites, and moreover, it was evident that ferrous artifacts, like the deadeye straps, disintegrated under the movement of water caused by the thrusters or the gentle nudging of the manipulator arm. The manipulator arm was deemed inefficient for small find gathering and stowed.

At 0539 on 27 July 2002, the submarine used its maneuvering thrusters to fan away an estimated 10-20 centimeters (4-8 inches) of sediment in the area immediately abaft of the pipeline, exposing frames and possibly ceiling planking. The angle of the row of keelson bolts indicated that the Mica shipwreck rested on the seafloor with a 10-15 degree list to port. After imaging the freshly exposed area, the submarine surfaced at 1000 on 27 July 2002.

The archeological crew discussed the progress made on the previous dive, and identified several challenges facing the next dive to the wreck site. The size of the submarine and the orientation of the shipwreck combined to make it impossible to reach the center of

the wreck with the manipulator arm. Working within the confines imposed by the currents, the archaeological team believed that additional areas of the wreck could be dusted off to expose structural timbers (Figure 15). With the new priority, it was time for the fourth submarine dive to the Mica wreck.



Figure 15. Bow area of the Mica shipwreck. Tips of the cant frames can be seen. The stem, along with the rest of the hull's exterior was covered with copper sheathing (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

At 1120 on 27 July 2002, Dr. Kevin Crisman descended to the wreck in *NR-1*. The first order of business was to make another plan view mosaic of the site from an altitude of 4.6 meters (15 feet). After completing the plan view imaging, the submarine pilots used

the bow maneuvering thrusters to dust off portions of the wreck abaft of the pipeline.

The area was reexamined after each dusting. The attempts uncovered numerous fragments of wood and metallic sheathing, as well as several unidentifiable fragments of wood and metal. The reference bar, which had been placed in the area on the previous dive, was picked up and stowed until work in the area was completed.

NR-1 then repositioned until the bow thrusters were immediately above the centerline of the wreck, abaft of the pipeline. Short blasts with the thruster uncovered some sticks or dunnage, spikes, a bottle base, and the remains of a chainplate. Near the chainplate was a deadeye strap with its base oriented towards the port edge of the wreck. A small metallic patch, likely an object related to the ship's pump, was also found in this area. The uppermost layers of sediment of the wreck site were easily removed by the submarine's thrusters, however, the deeper layers were heavily consolidated and could not be dispersed. The thick sediment covering the frames and planking probably contained well preserved ship timbers and other artifacts. Wherever copper alloy fasteners were present, the ship timbers appeared to be intact. The effects of hull composition and the deep ocean on wreck preservation will be discussed more fully in Chapter IV. During the dive several *Teredo navalis* tubes were observed on the site. It is unknown whether these worms were attached to the ship at the time of the sinking, or whether they infested the wreck once it had settled on the seafloor. Dr. Crisman noted that the worm tubes could easily be mistaken for manmade objects.

After working in the center of the wreck abaft of the pipeline, the submarine moved into the port bow area. Here, two more chainplates were noted, both along the starboard side. The uppermost edges of the external hull planking and the copper sheathing appeared to be fragile and unconsolidated (Figure 16). They crumbled slightly during an attempt to remove sediment from the bow area using *NR-1*'s thrusters. This dusting was advantageous because it clearly showed that the ship was sheathed with wide thin planks, which were sandwiched between the narrower, thicker external hull planking and the metallic sheathing.

During that maneuver, it was noted that driving the submarine along the bottom became more difficult because the previously made tire tracks would catch *NR-1*'s wheels, causing the submarine to slide to port or starboard. Dr. Crisman noted that the hull planking was attached to the frames with what appeared to be copper alloy fasteners; the ends of some fasteners were bent or twisted. Before leaving the area, the manipulator arm placed the reference bar in the center of the wreck, immediately forward of the pipeline.



Figure 16. Starboard bow quarter of the Mica shipwreck. The edges of the sheathing and hull appear brittle and unconsolidated. Note the copper sheathing on the stem (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

After investigating the bow area, the submarine moved into the area immediately aft of the stern, to prepare for the removal of a portion of the sternpost and obtain metallic sheathing samples. The crew used the thrusters to clear away several layers of sediment, but failed to uncover any retrievable diagnostic artifacts. After examining the sternpost, the crew determined that the best way to remove it was to nudge the topmost portion of the stern with the submarine hull, causing it to snap at the weakest part, immediately below the uppermost gudgeon (Figure 17). The operation was successful, and the submarine manipulator arm picked up the sternpost with the gudgeon and some metallic sheathing still firmly attached. Before moving away from the wreck site, *NR-1* took digital images of the lower gudgeon (still attached to wreck), skag, and the detached sternpost. The manipulator arm was retracted, with the retrieved sternpost being held firmly in the jaws of the tool. The crew of the submarine took turns crawling down into the observation area and viewing the sternpost through the view ports. A post-excavation survey of the vessel showed it to be structurally stable, with the intact keelson and keel withstanding the weight of the pipeline and the stress placed on the hull by the submarine. After retrieving the sternpost, the submarine moved away from the site and waited for dawn before surfacing.



Figure 17. Perspective view of the starboard stern quarter of the Mica shipwreck. Two gudgeons are clearly visible, with the skag also still attached (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

An unfortunate accident occurred as *NR-1* ascended from the Mica wreck site. When the submarine was approximately 45.7 meters (150 feet) below the surface, the external hydraulic system began to lose pressure. The manipulator arm, which was powered by this system, began to lose its grip on the sternpost. In a matter of moments, as the pressure of the system fell below that of the surrounding seawater, the jaws on the manipulator lost their grip, sending the sternpost sinking to the bottom for the second

time in the Mica wreck's history. The submarine surfaced at 0845 on 28 July 2002.

Subsequent searches for the sternpost proved to be futile.

After the fourth dive had been completed, the captains of *NR-1* and *SSV Carolyn Chouest* determined that both vessels were in need of repair and maintenance. They decided to cut the mission short and return to port. *SSV Carolyn Chouest* towed *NR-1* to Pensacola, Florida, where the archaeological team unloaded the artifact retrieval system and the remotely operated vehicle handling and control equipment (Figure 18). Copies of the digital footage taken by the submarine were made and distributed among the archaeological team for further analysis.

The first round of excavations at the Mica wreck site yielded much information, and raised even more questions. In August 2002, several weeks after returning to shore, the archaeological team received an invitation to accompany a deep ocean survey expedition that was working in the area of the Mica wreck. The Sustainable Seas Expedition, under the direction of Dr. Sylvia Earle, offered to visit the wreck site using one man submersibles known as *DeepWorker* and *DeepRover*. These submersibles were equipped with high resolution digital cameras and manipulator arms, making them an ideal platform from which to record images and retrieve artifacts. The submersibles were extremely agile, and capable of taking high resolution digital color images from profile and perspective positions. After reviewing the final plan view images taken by *NR-1*, the



Figure 18. The crew of the SSV *Carolyn Chouest*. Seen here preparing to take the submarine *NR-1* under tow towards Pensacola, Florida (Photograph by author).

archaeologists identified several artifacts which they deemed as archaeologically significant. These items included a glass bottle bottom, ceramic shards, metallic sheathing, and copper alloy ship fasteners. Unfortunately, mechanical problems on the surface support vessel *MSV Ocean Project* prevented the expedition from ever reaching the site.

A third opportunity to visit the site was made possible when Deep Marine Technology, Incorporated, an offshore services company based in Houston, Texas, offered to visit the wreck area. They donated four days of ship time on the surface support vessel *Rylan T*, along with a remotely operated vehicle, and several trained pilots (Figure 19). After several delays due to bad weather, members of the archaeological team once again visited the site in January of 2003. Deep Marine Technology designed, built, and deployed an artifact retrieval basket to transport artifacts from the seafloor to the surface. The company also brought along one *DeepWorker* one-man submersible.



Figure 19. Deep Marine Technology's *MaxRover* being deployed over the Mica site. Note the artifact retrieval basket attached to the manipulator arm on the remotely operated vehicle (Photograph courtesy of Brett Phaneuf).

Early on 15 January 2003, the remotely operated vehicle *MaxRover* located the Mica wreck and briefly surveyed the area. The archaeologists noted that at least 5 centimeters (1.96 inches) of sediment had been deposited on the wreck site over the course of the last six months, obscuring the artifacts previously visible on the surface. Two rows of copper alloy spikes, protruding 0.15 meters (0.5 feet) from the seafloor, were found approximately eight meters (26.3 feet) west of the wreck, running parallel along the port

edge. The spikes could have attached external hull planking or wales to the upper hull frames. The remotely operated vehicle attempted to remove an entire sheet of metallic sheathing from the port midships section, but only succeeded in removing a small sample, with no visible identification marks. The *MaxRover* vehicle surveyed the port stern quarter of the vessel, and the archaeologists noted that the metallic sheathing had been peeled away, making it easier to grab with the manipulator arm. However, before the vehicle could obtain a sample of sheathing in that area, the main power supply cable failed, causing the pilots to lose telemetry with the *MaxRover*. The remotely operated vehicle was winched to the surface, but the artifact retrieval basket, containing samples of the metallic sheathing, remained inside of the hull on the bottom.²

² On the return voyage, the crew of the *Rylan T* fixed the power cable and dived on a nearby unidentified wreck. The 57.9 meter (190-foot) vessel, later identified as *Western Empire*, sprung a leak and sank on September 18, 1876, drowning ten men.

CHAPTER III

DESCRIPTION OF THE MICA WRECK AND ANALYSIS OF ITS ARTIFACTS

The following section contains a brief physical survey of the Mica shipwreck site as recorded by the archaeologists, followed by a description and analysis of the artifacts recovered.³ The hull of the shipwreck will be discussed, focusing first on general characteristics and then moving toward specific features. Although the archaeologists were only able to recover a very limited amount of artifacts, the ones that were retrieved provided clues about the vessels design, construction, and outfitting. Three types of artifacts were collected, including wood samples, a lead pipe, and metallic sheathing and associated fasteners. The archaeologists believed that analysis of the wood samples would provide information on what kind of timber was used to build the vessel, and from where it was harvested. Large enough pieces of wood from the vessel could also be used to examine fastening patterns and be dated via dendrochronological analysis. The archaeologists hoped that the lead hawse pipe and metallic sheathing were stamped with a maker's marks or other identifying feature that could provide clues to the origin of the shipwreck (metallic sheathing commonly had maker's marks stamped near the edge of each sheet). The sheathing could also serve as a temporal diagnostic artifact, because the rapid technological evolution of ship sheathing material provided date ranges for its manufacture and use. Digital documentation of other artifacts, including rigging

³ A full description of the recovered artifacts can be found in the artifact catalog in Appendix B.

elements, frames, and metallic spikes, were utilized by the archaeologists, however, several centimeters of sediment covered many of the artifacts, hampering archaeologist's efforts to positively identify them *in situ*.

The Mica wreck sat upright on the seafloor, approximately two meters (6.6 feet) high in the bow, and three meters (9.8 feet) in the stern. The hull form was extensively examined, with the overall dimensions being recorded from the side scan sonar record. The stem and sternpost were plotted and the distance between them found to be 20.5 meters (67 feet) along the keel. Figuring the rake of the posts and the likely placement of the deck, it was estimated that the vessel's length on deck was 21.9 meters (72 feet). Using the dimensions for overall length on both the deck and the keel, and coupling that information with the hull form, a picture of the probable vessel type emerged. The Mica vessel was somewhat long for a single-masted vessel like a sloop, but too short to step three masts, narrowing it down to being a two-masted vessel, most likely a brig or a schooner.

The investigation did not recover any rigging elements or specific evidence of rig type or sail arrangement, however, evidence of mast placement was collected by noting the position of possible chainplates and deadeye straps. Three possible groups of chainplates and deadeye straps were found, one on the port side of the wreck just aft of amidships and one on either side of the vessel several meters aft of the bow, indicating that the vessel had at least two masts (Figures 20 and 21). The vessel could also have been a

lightly built warship, although no evidence of guns, gun ports, or other armament was discovered. If it was a merchant vessel, it would have more than likely been rigged as a schooner, because of the inherent qualities that the schooner rig provided, namely the reduction in manpower required to operate the sails, and the excellent maneuverability in hazardous coastal waters. The dimensions of the Mica wreck coincided with the average range of the ubiquitous two-masted merchant schooners that sailed along the coasts of the early American republic.

There were numerous objects resembling blocks scattered about the surface of the wreck, however, it is possible that these were clams covered over by sediment. In the bow area, cant frames were visible, but badly deteriorated, probably due to marine borer damage. The entire hull surface of the bow was covered with metallic sheathing, including the stem and the sheathing had developed a dull green patina. Each sheet of metal overlapped and was fastened to the hull with nails or tacks that also had a dull green patina. There were nails fastened in evenly spaced diagonal rows across the face of each piece of sheathing, resembling the quincunx pattern seen on the five side of a die. Inside the bow, there were approximately two meters (6.6 feet) of sediment, which sloped down towards amidships. The lead hawse pipe was retrieved from inside the bow area by the pipeline survey crew, although the exact location was not noted, because they collected the artifact before archaeologists could document the site.

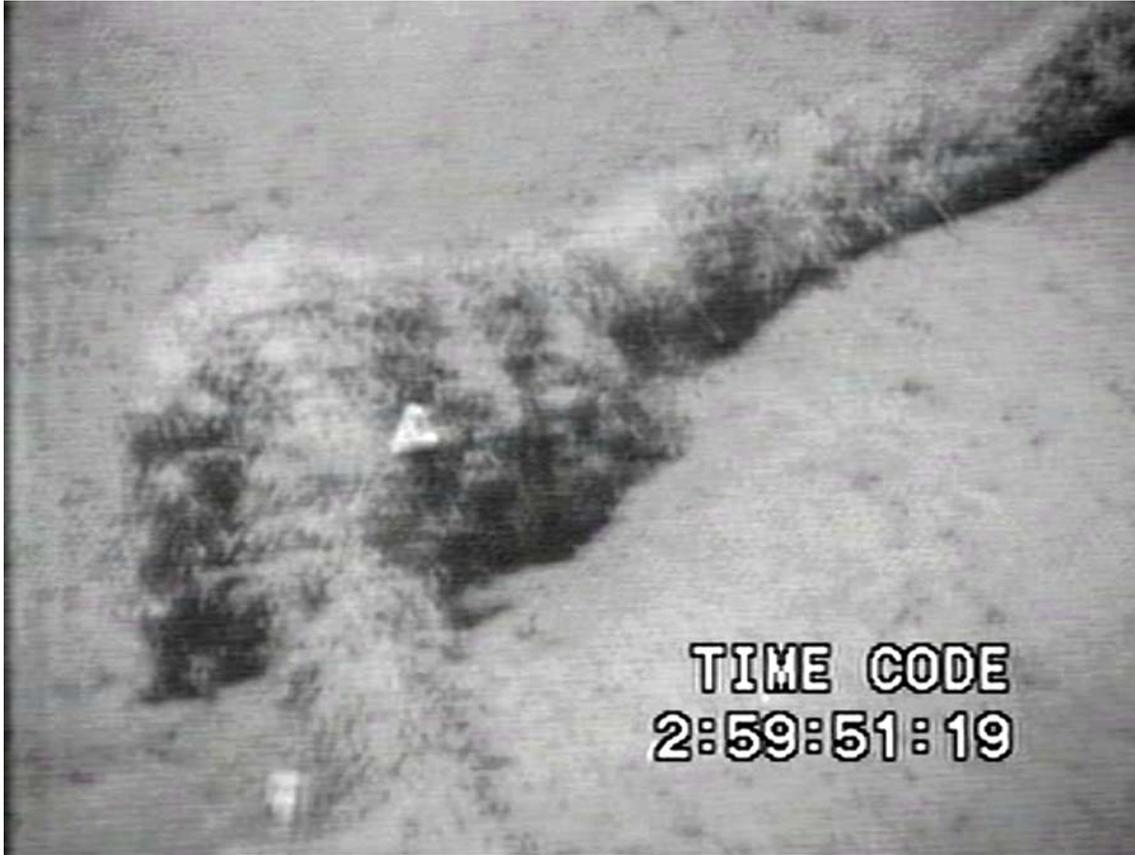


Figure 20. Possible remains of a chainplate or deadeye strap seen aft of amidships on the port side (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

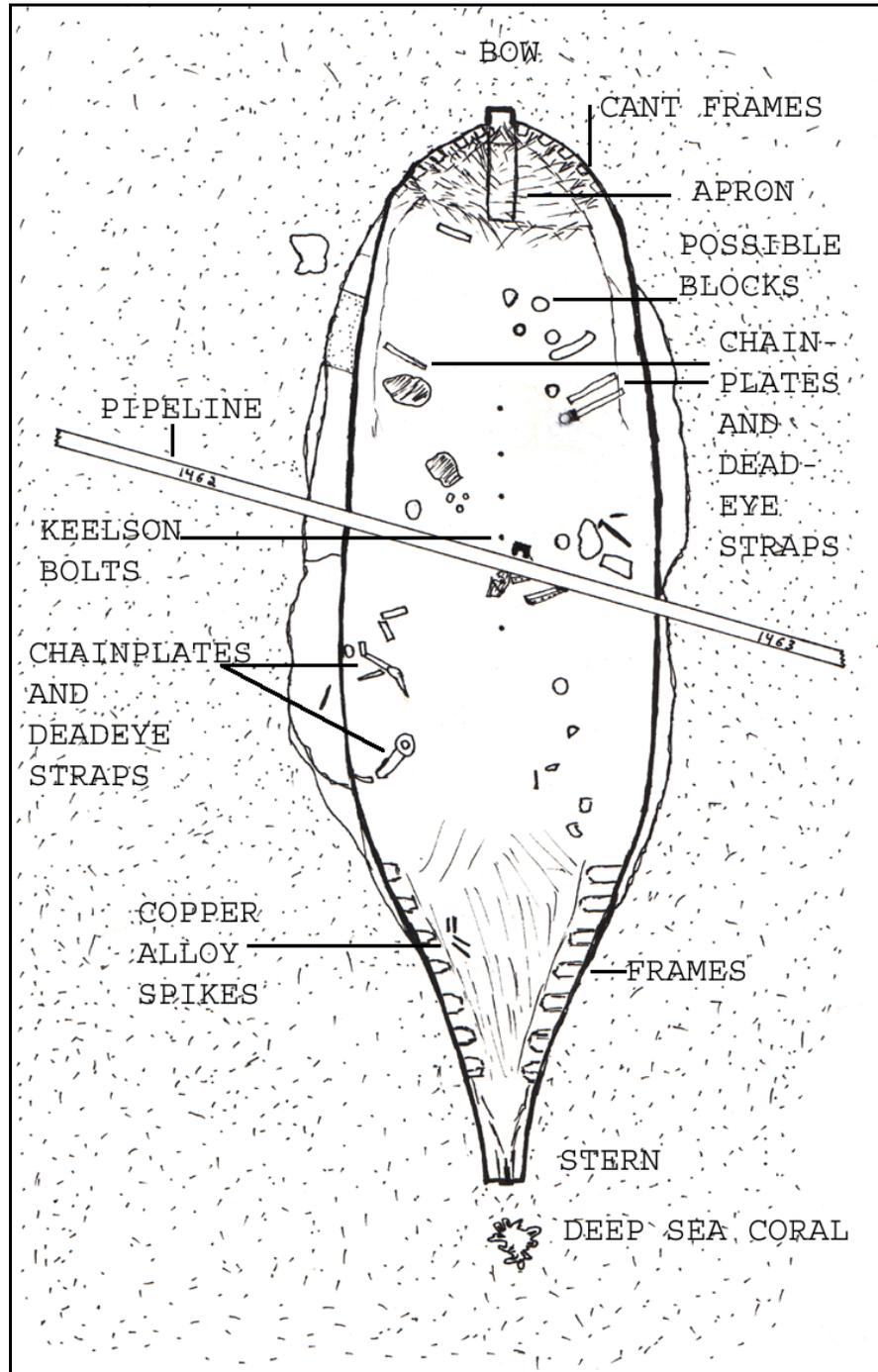


Figure 21. Site plan drawing of Mica shipwreck. It should be noted that the spatial relations of the artifacts are relative (Drawing by author).

In several areas of the bow and stern the sides of the ship had fallen away and out, but were still attached to the hull along the bottom edge (Figure 22). In these areas, the archaeologists noted that there was a layer of intermediate planking between the metallic sheathing and the hull. This layer, known as sacrificial planking, is normally found on vessels that were not sheathed with metal. It was curious that there would be two types of sheathing, one on top of the other, on the same vessel. That unique feature will be discussed more fully in Chapter IV.

The pipeline appeared to spread open even more of the wreck, pushing the frames, hull planking, and sheathing from a near vertical to a horizontal position. Sediment still covered the interior of the vessel, although the maneuvering thrusters on *NR-1* uncovered frames and possibly ceiling planking. A line of keelson bolts was visible running down the center line of the vessel near amidships. The bolts appeared to fasten the degraded keelson to the floor timbers and keel. A fragment of the keelson was visible immediately aft of the pipeline on the centerline of the wreck. Moving aft, a pile of large spikes, probably copper alloy, were seen near the port stern quarter of the wreck. The spikes, which were too large to attach metallic sheathing to the hull, were probably used to fasten the exterior planking to the frames. The pile was probably formed by the slow disintegration of a frame that contained numerous spikes.

On the opposite edge of the wreck, one of the archaeologists noted a ceramic or glass bottle base protruding from the sediment. The white item appeared to have a thin dark

green line on it, possibly a decoration. Unfortunately, this potentially diagnostic artifact could not be recovered.

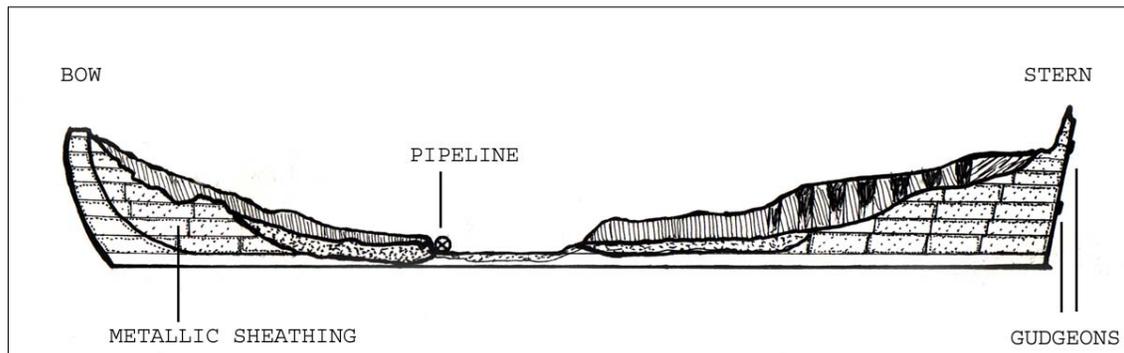


Figure 22. Profile drawing of the Mica shipwreck. Note the pipeline forward of amidships (Drawing by author).

In the stern of the wreck, archaeologists obtained detailed images of the metallic sheathing, as well as the sternpost, two gudgeons, and skeg. As mentioned earlier, there was no evidence of the rudder itself. A piece of deep ocean branching coral, was lying on the seafloor immediately aft of the sternpost. It was likely that the coral was growing on a part of the wreck that eventually collapsed, sending it to the seafloor. The archaeologists noticed the lower parts of the external hull were discolored, where the wreck had sunk into the sediment. The weight of the pipeline had lifted the ends of the wreck out of the sediment, apparently without breaking the keel. As noted in the previous chapter, the top portion of the sternpost was removed, leaving the wreck site with one intact gudgeon and the skeg available for future research.

WOOD SAMPLE ANALYSIS

After the archaeological field research had been completed, the archaeologists turned their attention towards identifying the Mica shipwreck vessel type, origin, and reasons behind its loss far offshore in the Gulf of Mexico. They were also interested in identifying the nature of the vessel's cargo, and assigning a name to the shipwreck. The scanty numbers of artifacts actually recovered has unfortunately limited the achievement of these objectives.

Several wood samples were retrieved at the time of the wreck's discovery. They appeared to be taken from the thin layer of planking that was sandwiched between the metallic sheathing and the hull planking in the port bow quarter (Figures 23, 24 and 25). The specimens were sent out to several tree identification laboratories. While there was an insufficient amount on which to perform dendrochronological analysis, the scientists were able to determine the species and probable location where the trees were harvested. Both laboratories, the Center for Archaeological Investigations at Southern Illinois University at Carbondale, and the College of Forestry at Mississippi State University, agreed that the wood samples were *Pinus strobus*, commonly known as eastern white pine. This species grows along the seaboard of Eastern North America. It is commonly found from the North Carolina-Virginia border north into Canada. The wood has a history of use in ship construction and is mildly resistant to rot and degradation. It

should be noted that the wooden specimens were consumed during testing and no longer exist.

Dave Johnson of Galvetech in New Orleans, Louisiana undertook the initial conservation of the wood and metal artifacts, including the hawse pipe. Barnacles and lead carbonate covered substantial portions of the internal and external hawse pipe. The amount of conservation carried out on the hawse pipe was unclear. The metallic sheathing fragments were treated using desalination and electrolytic reduction cleaning. None of the metallic sheathing fragments appeared to have been sealed, and were experiencing extensive tarnishing. They were retreated by the author at the Conservation Research Lab at Texas A&M University. The pieces were mechanically cleaned with glass bristle brushes and then immersed in benzotriazole and finally coated with Krylon 1301 clear matte acrylic spray (Figure 26).

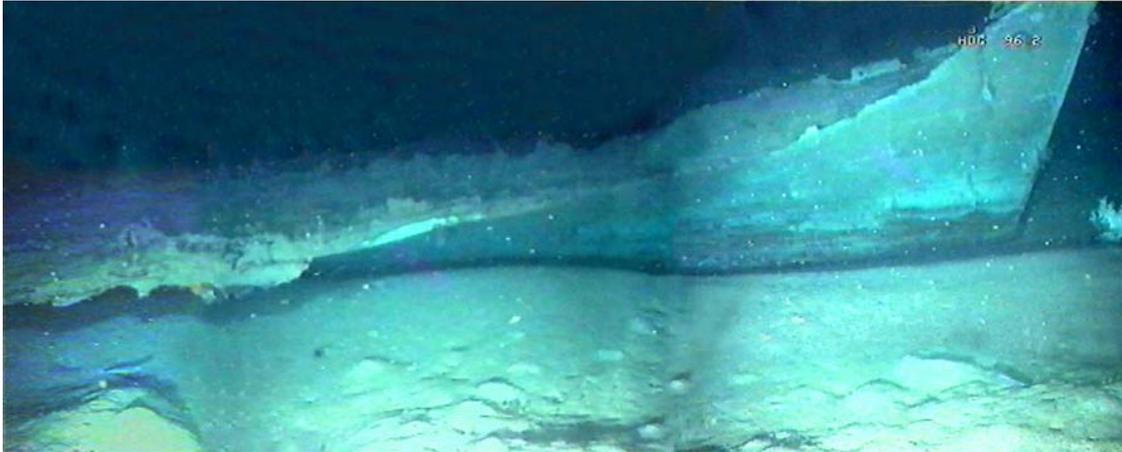


Figure 23. Profile view of the port stern quarter of the Mica shipwreck. The thin sacrificial planking can be seen attached to the copper sheathing. The laying of the pipeline caused the gunwales of the vessel to spread outward near amidships (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

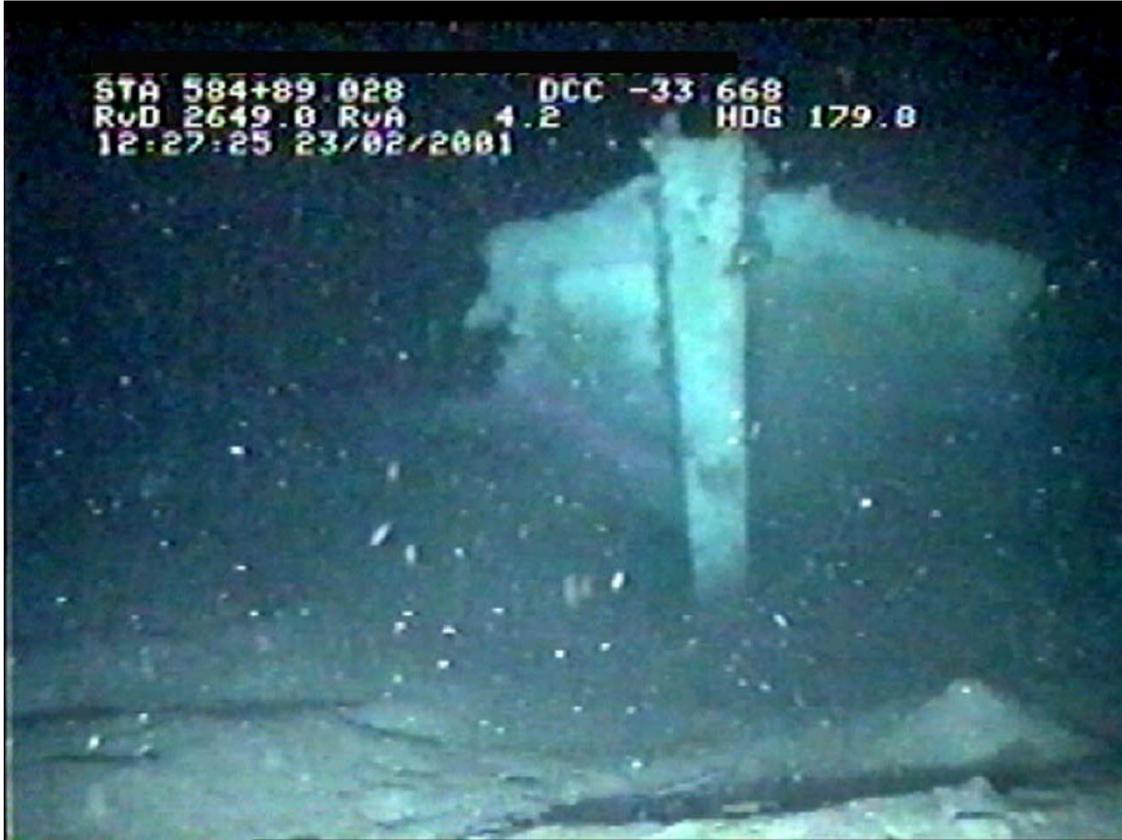


Figure 24. Photograph of stem and bow of Mica shipwreck (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).



Figure 25. Photograph of starboard stern quarter of Mica shipwreck. Note the amount of sediment present inside of the wreck (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).



Figure 26. A fragment of the copper sheathing retrieved from the Mica shipwreck. The bright spot in the lower right corner has been mechanically cleaned with a glass bristle brush (Photograph by author).

METALLIC SHEATHING AND FASTENER ANALYSIS

The elemental compositions of the metallic sheathing samples from the Mica shipwreck were determined using a refracting electron microprobe and an atomic absorption mass spectrometer. Both analyses were performed by laboratories at Texas A&M University. The refracting electron microprobe composition analysis was performed by Dr. Renald Guillemette on a four spectrometer Cameca SX50 electron microprobe using energy dispersive spectroscopy. Dr. Guillemette is the director of the Electron Microprobe Laboratory in the Department of Geology and Geophysics in the College of Geosciences. The atomic absorption mass spectrometer tests were performed by the Office of the Texas State Chemist at Texas A&M University.

Each of the testing processes offered a high degree of accuracy, with the atomic absorption mass spectrometer tests requiring less sample preparation than that of the refracting electron microprobe. However, the use of the microprobe allowed for examination of the grain structure as well as spot analysis of impurities. The atomic absorption test required the consumption of a small amount of sheathing, which was dissolved in acid. The procedure caused any impurities present to be mixed with the primary metal. The electron microprobe used x-rays to analyze the artifacts in a non-destructive manner. The microprobe determined the grain structure of the metal as well as the frequency of any impurities. The instrument was even capable of detecting trace elements within the impurities.

In order to analyze samples on the refracting electron microprobe, small pieces of sheathing were bedded on edge in epoxy (Figure 27). The face of the block was polished to expose a fresh surface of metal, and then coated with a fine layer of pure powdered carbon. By focusing the x-rays on a freshly cut edge, the probe could avoid areas where superficial corrosion had altered the structure and composition of the metal. While the sheathing fragments were not destroyed, they remained permanently embedded in the clear epoxy carrier. The electron microprobe allowed more in-depth and varied analyses, however, it was also more labor-intensive and slightly more expensive to use when running a small number of samples.

The metallic sheathing and fasteners from the Mica shipwreck were tested using both methods mentioned above, with nearly identical results. The vessel was sheathed with copper sheets that were an alloy of 99.5 percent copper, with traces of arsenic.⁴ The sheathing nails were a brass alloy containing 84.7 percent copper, alloyed with 5.3 percent tin and 7.8 percent zinc. The fasteners contained traces of lead, arsenic, and bismuth. After being mechanically cleaned, the fasteners were a yellow brass color, noticeably different from the reddish-yellow color of the copper sheathing. The properties of the sheathing and fasteners, which were used to help date the shipwreck, are discussed more fully in the following chapter.

⁴ Complete metallic sheathing analysis results can be found in Appendix C



Figure 27. The refracting electron microprobe sample carrier. It contains pieces of metallic sheathing awaiting analysis (Photograph courtesy of Dr. Renald Guillemette).

By the end of the eighteenth century, shipbuilders were aware of the causes of electrochemical corrosion between dissimilar metals. To prevent the preferential corrosion of one metal, both metals (in this case, the sheathing and the fasteners) were made similar in composition. However, pure copper fasteners were too weak to be driven into the planking. They were either alloyed with small amounts of harder metals or mechanically strengthened during the manufacturing process by rolling the fasteners through grooved rollers or by a process called annealing. Annealing was the most common method, and involved controlled heating and cooling of the metal to improve the grain structure and density, with a corresponding increase in strength. The nails on the Mica shipwreck obtained their strength from their alloy composition, not from annealing or rolling.

To save labor and reduce wastage, copper sheets used for ship sheathing were mechanically punched, with the first punching machine being patented in 1830.⁵ The machine produced pre-punched sheets of metallic sheathing, with regularly spaced holes for the nails. The sheets could be rapidly applied to the hull of a vessel. The nail holes on the Mica shipwreck were not at regular intervals, nor in straight lines, indicating that they were not pre-punched (Figure 28). The nails were also not of a uniform size and shape. Where one sheet overlapped another, there were closely spaced nails along the edge. The lack of regular spacing between fasteners also suggests hand-punching of the sheathing on the Mica shipwreck.

⁵ Gray 1830, 173.



Figure 28. Detail of the starboard stern quarter of the Mica shipwreck. Note the dense nailing around the edges and the quincunx pattern in the middle of each sheet (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).

Several fragments of sheathing from the Mica shipwreck were from the edges of sheathing plates. The largest fragment of sheathing retrieved also contained two corners, comprising the edge of a 36 centimeter (14 inch) wide sheet (Figure 29). The amount of sheathing overlap, 4 centimeters (1.5 inches), was determined from this piece. The sheathing on the wreck appeared to overlap on the lower edge of each sheet, in the same

manner as roofing is applied today. This method indicates that the vessel was sheathed beginning at the keel and moving upwards toward the gunwale.



Figure 29. Largest fragment of metallic sheathing recovered from the Mica shipwreck (Photograph by author).

No maker's marks or gauge stamps were found on the sheathing samples. These marks were customarily placed near the edge of a sheet. There were full sheets still attached to the wreck, so it is not improbable that a maker's mark will someday be found. If discovered, the maker's mark might reveal the location and possibly the date of the sheathing's manufacture. If company records are extant, they might contain details about the ships sheathed in the material, or where the sheathing was shipped for sale. Metallic

sheathing was an expensive option, so it was unusual to find it on such a small vessel.

One primary source indicates that copper-sheathed merchant vessels were an exceedingly rare sight through the 1790s.⁶ This information suggests the earliest probable building date to be after 1800.

A visual analysis of the fasteners from the Mica wreck revealed irregularly shaped heads and shaft lengths. The nails appeared to be cast, because they were porous, however, the porosity may also have been due to the preferential corrosion of zinc and tin from the fasteners. Cut nails were not in widespread use until the 1830s, but hand-wrought nails continued to be used through mid-century, so that diagnostic attribute remains inconclusive. When the fastener information was coupled with the hand-punched sheets, it suggested that the ship was sheathed for the last time sometime before the advent of mechanical manufacturing processes for metallic sheathing. It is also possible that the vessel, being a small merchant trader, may not have been sheathed in a location equipped with a mechanical press. The sheathing sample could also have been retrieved from a location on the ship where a pre-punched sheet would not fit, necessitating the use of a hand-punched one.⁷

⁶ Childers 1970, 41.

⁷ Hall 1884, 127.

LEAD HAWSE PIPE ANALYSIS

The lead hawse pipe found on the Mica shipwreck was 17 centimeters (6.8 inches) in diameter and 41 centimeters (16.2 inches) long (Figures 30, 31 and 32). The thickness of the hawse pipe wall averaged 2 centimeters (0.5 inches). The hawse pipe appeared to be poured or formed with eight longitudinal seams, which were evident on both the internal and external surfaces. The average width between the seams was 7 centimeters (2.5 inches). An examination of the wear patterns on the lead artifact revealed that it was probably the starboard hawse pipe. The lower outboard lip was substantially worn, probably from the rubbing of an anchor cable or chain while the vessel was riding at anchor. There were several deep cuts near the inner end of the hawse pipe, which might indicate that the anchor line was cut in a hurried manner (Figures 33 and 34).

Metallurgical analysis of a small sample taken from the hawse pipe revealed that it was composed of lead with traces of copper and bismuth. Lead is easy to smelt and almost any impurities can be readily removed, accounting for the near pure composition of the hawse pipe. Lead from another shipwreck, as well as modern lead, were tested and found to be nearly identical in purity and grain structure to the lead found on the Mica shipwreck. No other identifiable hawse pipes or scuppers were seen around the wreck, but fragments of lead were seen elsewhere, possibly from the other hawse pipe, scuppers or the ship's pump(s).



Figure 30. *In situ* photograph of the starboard lead hawse pipe on the Mica shipwreck (Photograph courtesy of the United States Minerals Management Service and ExxonMobil Corporation).



Figure 31. Forward face of lead hawse pipe from the Mica shipwreck. Casting seams are evident on the both the external (right) and internal (left) openings (Photograph by author).



Figure 32. After face of conserved lead hawse pipe from the Mica shipwreck. Casting seams are evident on the both the external and internal surfaces (Photograph by author).



Figure 33. Interior opening of conserved lead hawse pipe from the Mica shipwreck. Note the possible cut marks on the curled-in exterior surface, visible in the lower left (Photograph by author).



Figure 34. Detail of cut marks near the interior opening of the hawse pipe. Analysis of wear marks and the location of the pipe on the wreck suggested that this was the starboard lead hawse pipe (Photograph by author).

WHAT CAN THE ARTIFACTS TELL US ABOUT THE WRECK?

An analysis of the Mica shipwreck's dimensions, hull form and limited artifact assemblage suggest that the vessel was most likely a two-masted fore-and-aft rigged coastal merchant schooner dating to the first half of the nineteenth century. The identification of the sacrificial planking as eastern white pine, coupled with the fact that

the vessel sunk near the Mississippi River mouth in the Gulf of Mexico, seem to indicate that the vessel was American built and possibly American operated. According to Chapelle, most American merchant shipping in the early nineteenth century was carried out by coastal schooners, which made short trips between ports carrying the bulk of trade goods during that period.⁸ Unfortunately, no evidence of the vessel's cargo was recovered during the investigation.

All of the visible hardware on the wreck, including the keelson bolts, gudgeons, skeg, hull planking spikes, metallic sheathing and the sheathing tacks all were or appeared to be manufactured from copper or copper alloy. These metals were expensive, and their presence suggests that the vessel was well built and well maintained. The added expense of alloyed hull fasteners may have been a necessity to avoid the corrosion of dissimilar metals in proximity or it may have represented an owner or shipbuilder that put quality before cost.

⁸ Chapelle 1935, 219.

CHAPTER IV

A BRIEF HISTORY OF METALLIC SHEATHING

The most important artifacts recovered during the Mica shipwreck investigation were fragments of metallic hull sheathing. Because hull sheathing underwent rapid technological evolution, it was possible to create a chronology of sheathing development. This was achieved by analyzing historical documents, patent records, and period sheathing advertisements and by performing composition analysis on sheathing fragments from shipwrecks of known provenience. By examining the sheathing on the Mica wreck and placing it within the sheathing chronology, the archaeologists were able to date the wreck in a very approximate way. The entire process will be explained below, after presenting a brief history of sheathing development.

This chapter will briefly explore the transition from organic sheathing (wood, fiber, and pitch/resins) to the more durable metallic sheathings (lead, copper, copper alloy, zinc, tin, and iron), looking specifically at mixed-metal or composition alloy sheathings.⁹ The development of different sheathing alloys and their relative effectiveness will be evaluated, through analysis of firsthand accounts and patent reports. An analysis of the initial success and subsequent precipitous decline of the Milled Lead Company of

⁹ The terms mixed-metal, composition, and alloyed metallic sheathing are used interchangeably. Types of metals discussed in this chapter and their elemental symbols: Iron (Fe), Copper (Cu), Lead (Pb), Zinc (Zn), Tin (Sn), Antimony (Sb), Bismuth (Bi) and Mercury (Hg).

England will be explored. It will be shown that the technological evolution of ship sheathing was not linear and progressive, but alternated between new innovations and old standbys. The patent specifications will be discussed chronologically, but it is necessary to note that there was often a substantial overlap in the acceptance of a new sheathing technology and the discarding of an older method. It is also important to remember that the date of a patent did not always represent the date that the new sheathing technology was created by the inventor or utilized by the industry. The development of new sheathing materials was a dynamic process that resulted in few instances of overnight changes to the status quo.

Preventing leakage as well as damage caused by marine organisms such as *Teredo navalis* and *Limnoria terebranshas*, was a necessary priority of the builders and owners of wooden ships. The damage caused by marine borers became increasingly acute in the early to middle sixteenth century, as European mariners began to routinely sail into tropical waters in both the Old and New Worlds, warm water being the preferred home of the destructive organisms. In the fifteenth and sixteenth centuries, the most common methods of protecting a ship's hull from the damage caused by marine organisms included charring, double planking, coating with chemical concoctions, and covering with hammered or cast sheet lead. A brief description and examples of each barrier are discussed below, along with a comparison of the advantages and disadvantages of each method.

Burning the surface of the external hull planking created a thick layer of charcoal, which was sealed with pitch and then smoothed over with tallow. A letter written to a French technological journal in 1666 proved most insightful concerning the methods and problems associated with charring a hull, as the following extract illustrates: “The *Portugals* scorch their ships, insomuch that in quick works there is made a coaly crust of about an Inch thick. But as this is dangerous, it happening not seldom, that the whole vessel is burnt.”¹⁰ It was thought that the worms were unable to digest the charcoal, which prevented them from boring further into the planking. In 1622, Richard Hawkins wrote that this was the most common method for protecting the hull of a vessel, and concerning its effectiveness, he wrote that “this is not bad.”¹¹

Double planking, also known as sacrificial planking, yacht planking or deal, was used by many nations.¹² William Petty of England related how wood sheathing was typically defined and applied before 1682:

First, That only competent and allowable *Defense* against the *Worm*, before this of *Lead-Sheathing*, was the paying of the Hulls from the Waters edge downwards with *Stuff*, and laying the inside of a Sheathing-board (from inch and quarter to three quarters thick) all over with *Tar* and *Hair*, to be brought over the forementioned *Stuff*, and being well nailed, *Graving* or *Paying* the outside of the said Board all over with another Composition of *Brimstone*, *Oyl*, and other *Ingredients*, which is called *Wood-Sheathing*.¹³

¹⁰ Royal Society of London. 1665/6. 190.

¹¹ Hawkins 1933, 81.

¹² Petty, 1691. 5.

¹³ Petty 1691, 36-37.

Hawkins related his belief that the borers were unable to digest the animal hair. He wrote that the most desirable wood for sheathing was elm, because it was more durable than oak, and conformed to the contour of the ship better. He also stated that the typical thickness of a double plank was 0.01 meters (0.5 inches), with the thinner planking performing better. The manner of covering the boards was similar to the way mentioned by Petty above, with generous amounts tar and hair being sandwiched between the two layers of wood. For attaching the boards to the hull, Hawkins said that nails, presumably of iron, should be no more than a hand span apart, with the most effective sheathing being the most densely nailed.¹⁴ The opinion held by Hawkins was that wood sheathing was the most cost-effective method of protecting a vessel against the ravages of the borers.

Wood sheathing was indeed economical and long-lasting compared to other sheathing materials (chemical concoctions and lead), but it was not without its drawbacks. The scarcity of locally available timber was a major concern, especially in times of war, when hostile nations might have been the only source of the desired planking. Petty listed another disadvantage, namely that unprotected wood sheathing was prone to rapid fouling, which affected speed and handling characteristics of the sailing vessel, meaning that the wood couldn't be employed alone. He also complained that the numerous nail heads protruding from the hull planking created excessive drag.¹⁵ Sheathed hulls had to

¹⁴ Hawkins 1933, 81-82.

¹⁵ Petty 1691, 38-39.

routinely be brushed clean to remove the accumulated algal colonization and barnacle growth, because of the drag they created. Petty relates how long-handled scrubbing brushes were used to clean the sides of the ship while at sea.¹⁶ These brushes could nearly reach the keel, lessening the need for frequent careening. However, the scarcity of suitable sheathing timber, and the fact that it was only effective at slowing, and not stopping, the progress of the marine borers, necessitated the development of a new sheathing material.

Mixtures of rosin, sulfur, tar, oil, and other substances, including crushed glass and hair, were often employed in the protection of hull planking.¹⁷ These substances could be used in conjunction with sacrificial planking, or applied directly to the external surface of the hull planking.¹⁸ The use of white stuff was common in the fifteenth and sixteenth centuries, and consisted of a blend of train oil (fish or whale oil), sulfur, and rosin. This mixture was mildly successful, but the expense of the rosin spurred investigation into cheaper alternatives. A mixture called black stuff was invented sometime in the seventeenth century. This compound consisted of two parts pine pitch to one part tar, and was heated and spread on the hull. To make it more effective, it could be mixed with crushed glass or other substances that would have a detrimental effect on the borer's progress.¹⁹

¹⁶ Petty 1691, 39.

¹⁷ Hawkins 1933, 81-82.

¹⁸ Hawkins 1933, 81-82. See also Petty 1691, 36-37.

¹⁹ Hawkins 1933, 82.

For the most part, the sheathing methods discussed above were merely hindrances to the marine borers. The sailors of the period were in dire need of a durable and impregnable barrier against the voracious shipworm. Some inventors began turning their attention towards metals, specifically lead and copper. Ships sheathed with cast lead, and to a lesser extent, hammered lead, were used during the sixteenth and mid to late seventeenth centuries, alongside ships sheathed with the abovementioned techniques.

LEAD SHEATHING

The use of lead as a sheathing material was not a technological innovation of the post-medieval era. Vessels in ancient times, for example the third century B.C. Kyrenia wreck and the first century A.D. Nemi barges were sheathed with hammered lead. However, the sheathing probably served a different purpose in antiquity. Because shipworms were not a widespread problem in the Mediterranean at that time, it is been hypothesized that the primary purpose of the hammered lead sheathing was to prevent leakage in the edged-jointed hull planking.²⁰ Yet, hand-pounded lead was expensive, of inconsistent thickness, and generally lacking in durability, making it likely to be employed on seldom-used royal ships, old vessels prone to leaking, or for emergency repairs.

In Europe, the use of lead as a sheathing material was revived in the sixteenth century, but it was needed for a different purpose. Instead of preventing water from entering the

²⁰ Hocker 1989, 197-198.

vessel, the sheathing was designed to provide a barrier between the hull planking and marine borers. Although hammered lead was still in use, a better method of casting the lead was discovered. Molten lead was poured into thin sheets, which were lighter and of a more consistent thickness than hammered lead. However, this new manufacturing process failed to produce sheathing that was long-lasting, with Hawkins commenting that “some sheath their Shippes with Lead; which besides the cost and waight, although they use the thinnest sheet-lead that I have seene in any place, yet it is nothing durable, but subject to many casualties.”²¹ This lack of durability was caused by the inconsistent thickness across each sheet. The sheets would heat and cool unevenly, causing cracks to form along the transitions between thick and thin areas on the same sheet.²² These cracks, often invisible to the naked eye, allowed access of the minute shipworm larvae, which according to Hawkins, entered the hull planking no larger than the diameter of a Spanish needle, and soon grew to be larger around than a man’s finger.²³ Hammered and cast lead had many problems, but inventors continued to refine the manufacturing process, in an effort to make the sheathing durable.

The invention of milled lead in the third quarter of the seventeenth century was seen by many as the long awaited solution to the shipworm problem. In 1670, a patent for the manufacturing process and marketing of the “New Invention of Mill’d Lead” was

²¹ Hawkins 1933, 81.

²² Hale 1695.

²³ Hawkins 1933, 81.

granted to Sir Philip Howard and Sir Francis Watson.²⁴ This act led to the formation of the Patent Milled Lead Company, which had a relatively brief and highly controversial existence. The manufacturing process called for the lead to be cast into thin ingots, and then rolled between drums, producing a uniform sheet of any desired thickness. The new sheets were denser, smoother, and not subject to cracking because of their consistent thickness.²⁵ In a period advertisement, Thomas Hale, an agent of the Milled Lead Company, stated that milled lead was, on average, 22 percent cheaper than the equivalent amount of cast lead.²⁶ He compared the initial costs of wood sheathing (10 pence per square foot), to that of milled lead (15 pence per square foot). The savings of using milled lead could be found in the reduction in annual maintenance costs, since the lead-sheathed hull required no graving, an expense of 40 pounds a year on a 600 ton merchant vessel.²⁷ When a ship finally needed to be stripped of its old sheathing, the ship owners were paid more by recyclers for the used milled lead, both because it was of a higher purity than cast lead, and because it was less corroded compared to the same amount of cast lead. Concerning performance, Hale claimed that milled lead made a ship stiffer, and kept the hull cool and dry, whereas wood sheathing absorbed water, which caused the oakum caulking to rot quickly.²⁸

²⁴ Petty 1691, 5.

²⁵ Bulteel. 1672 6193.

²⁶ Hale 1695, 2.

²⁷ Hale 1695, 4.

²⁸ Hale 1695, 4.

The Royal Navy, seeing the strategic advantages of a long-lasting and impenetrable hull sheathing, ordered 20 ships to be sheathed with milled lead. *Phoenix* was the first ship which was fully sheathed with milled lead in March 1670. That vessel was soon followed by *Dreadnought*, *Henrietta* and 17 other warships. *Phoenix*, having completed two voyages to the Straits of Magellan, was inspected by King Charles II during a routine careening in 1673.²⁹ The king was so impressed that, in December of 1673, he ordered all Royal Navy vessels to be sheathed exclusively with lead.³⁰ Bulteel enthusiastically added that the sheathing “was found to be in as good condition, as at first doing.”³¹ By 1675, the trials had been deemed successful, with the Admiralty granting the Milled Lead Company a 20-year contract for the exclusive sheathing of English naval vessels.

The celebration at the Milled Lead Company was, however, short-lived. Reports of major problems began to trickle in from ships based in distant ports. All the descriptions shared similarities with the following excerpt:

From abroad, of a quality discovered in our Lead-sheathing, tending (if not timely prevented) to the utter Destruction of his Majesties Ships, namely, That of the *Eating* into, and wasting their *Rudder-Irons* and *Bolts* underwater, to such a degree, and in so short a space of time, as had never been observed upon any unsheathed or Wood-sheathed Ships.³²

²⁹ Bulteel 1672, 6192.

³⁰ Petty 1691, 6-7.

³¹ Bulteel 1672, 6192.

³² Petty 1691, 9.

Among the officers of the affected vessels, there was a consensus that the iron hull fasteners, especially the rudder irons and bolts, were experiencing accelerated corrosion. The cause or process was unknown, but the common connection was that the increased corrosion was occurring exclusively on lead-sheathed vessels. The officers brought several complaints to the attention of the Admiralty. In April 1678, the Admiralty opened an official inquiry into the effectiveness of milled lead sheathing and its purported negative effects on iron fasteners. This action set off a contentious debate between the Milled Lead Company and the officers of the Royal Navy.

Neither the Milled Lead Company nor the Royal Navy officers were objective in their treatment of the corrosion problem. It is important to briefly identify the motives driving each party. The Milled Lead Company was a commercial venture that had risked its existence on the viability of one product, and as such, they expounded its harmless nature, even in the face of overwhelming evidence to the contrary. Some of the officers held financial stakes in companies whose materials were no longer being utilized by the Royal Navy for sheathing.³³ Other officers wanted to absolve themselves of blame, as the corrosion of the rudder hardware could be mistaken for poor maintenance of a vessel, which would tarnish their service records. The Admiralty would, of course, side with the officers, but they also had to accommodate King Charles II, who had enthusiastically approved the use of milled lead.

³³ Petty 1691, 61.

The inquiry opened with the officers relating vivid descriptions of the accelerated corrosion on 13 vessels, which they believed was due to the lead sheathing. The third rate HMS *Dreadnought*, sheathed in 1671, was inspected in 1676, with her rudder irons, pintles and gudgeons being routinely replaced. During a subsequent inspection 18 months later, the iron fasteners were found to be “very much eaten and consumed, and not to be trusted at Sea.”³⁴ The afflicted hardware was replaced, and the ship was inspected again on October 8, 1682, when it was discovered that nearly all of the iron fasteners in the stern were completely dissolved, with the hull being held together by rust and dirt.³⁵ HMS *Lyon* was sheathed with lead in 1672, and inspected in October 1677. The iron bolts under the sheathing were found to be badly corroded, “insomuch that some were gotten out by the Caulkers with their Spike-irons...the like whereof the Officers at *Portsmouth* say, they have never found in any Ship not sheathed with Lead.”³⁶ The vessel subject to the fastest corrosion was HMS *James Gally*. After being sheathed in October 1676, she was inspected five months later, when her rudder irons were found to be completely dissolved. These were replaced, and a follow-up examination in October 1677 found them to be again dissolved into numerous pieces.³⁷

It seemed clear to the Royal Navy that the presence of the lead sheathing was having a deleterious effect on the iron hardware. In light of these accusations and strong

³⁴ Petty 1691, 45.

³⁵ Petty 1691, 45.

³⁶ Petty 1691, 45-46.

³⁷ Petty 1691, 47.

supporting evidence, the Admiralty was poised to recommend that the use of lead as a sheathing material be discontinued until the corrosion problems could be addressed.

The burden of proof fell squarely on the Milled Lead Company, and they were prepared to fight for their continued existence. They began to systematically challenge the conclusions reached by the officers and the Admiralty. It is important to remember that their arguments, briefly discussed below, demonstrated the current knowledge of chemistry. Yet some of their arguments were contradictory to each other and occasionally sounded desperate.

The Milled Lead Company opened its defense by accusing the naval officers of bringing suit against the company in an effort to distract the Admiralty from the supposed true cause of the vessel hardware corrosion, namely dereliction of duty by the officers, specifically when it came to routine hull maintenance.³⁸ The company also claimed that the problems with the lead sheathing were being fabricated or exaggerated by those officers who held a financial stake in the companies that dealt with the previously used sheathing materials like wood and ‘stuff’ (various mixtures of rosin, tar, sulfur and oil).³⁹ The companies using the older technologies were now prevented, by Royal decree, from sheathing naval vessels, although the vastly larger merchant fleet still required hull protection.

³⁸ Petty 1691, 55.

³⁹ Petty 1691, 61.

When that argument failed to persuade the Navy Board, the Milled Lead Company tried a case-by-case refutation of the charges, saying that the corrosion of the iron fasteners was an intrinsic characteristic of the hardware. They meant that the blacksmiths who made the hardware and fasteners were improperly mixing or tempering the iron, causing it to corrode at an unusually high rate.⁴⁰ However, it is highly unlikely that all of the lead-sheathed ships were receiving poorly manufactured hardware, while the unsheathed and wood-sheathed vessels were supplied with only quality ironwork.

Perhaps the strongest argument placed forth by the Milled Lead Company was the fact that unsheathed, wood-sheathed, and lead-sheathed vessels all experienced some corrosion of the iron hardware. It was known that iron corroded in the presence in saltwater, but that fact didn't account for the differing rates of corrosion according to sheathing types. The company argued that if the lead sheathing was responsible for the accelerated iron corrosion, than all the iron on a lead-sheathed vessel would be uniformly corroded. In support of this, they showed that certain vessels, both lead-sheathed and wood-sheathed, had some fasteners that were heavily corroded, while nearby fasteners were as solid as the day they were put in.

Although contradictory to the claim that all of the lead-sheathed ships received faulty hardware, the Milled Lead Company expanded upon the argument that the difference in corrosion rates could be accounted for by the amount of saltwater a fastener was exposed

⁴⁰ Petty 1691, 23.

to. They claimed that a properly prepared fastener, meaning one that had been sealed, or parceled, with tar and hair, was impervious to the saltwater, and therefore, the associated corrosion.⁴¹

The reason the iron fasteners were subject to accelerated corrosion when in the presence of lead sheathing was not a coincidence, and can be determined by analyzing the arguments listed above. If the iron fasteners corroded when they came into contact with saltwater on an unsheathed vessel, it meant that the iron was reactive with the saltwater. If the iron fasteners corroded at an accelerated rate when in the presence of lead sheathing and saltwater, it meant that the lead acted as a sort of catalyst for the reaction between the iron fasteners and the saltwater.

What was not known during this period was the chemical reaction known as electrochemical corrosion. The reaction is based on the fact that some metals are more noble than others, and when the metals are placed in proximity to one another, along with the presence of an electrolyte, the less noble metal will sacrifice electrons to the more noble metal, causing the decomposition of the less noble metal (Table 1). Iron is less noble than lead, and saltwater was an ideal electrolytic solution. In the twentieth century, chemists have proven that these reactions were the underlying cause of the accelerated corrosion of iron hardware in the presence of lead hull sheathing. However, this information was not known during the seventeenth century. The reasons supplied by

⁴¹ Petty 1691, 25.

the Milled Lead Company claiming that the lead sheathing was not the cause of the severe iron deterioration were mostly plausible, given the contemporary state of knowledge concerning chemical reactions.

Table 1. The Relative Electromotive Force of Selected Metals (After Hamilton 22 February 2004, Online Conservation Research Laboratory Manual).

Noble Metals (More Cathodic) (Gain Electrons)	
Gold	[Aurous (+1), and Auric (+3)]
Silver	(+1)
Copper	[Cuprous (+1)]
Copper	[Cupric (+2)]
Hydrogen	(+1) (Neutral)
Lead	[Plumbous (+2), Plumbic (+4)]
Tin	[Stannous (+2), Stannic (+4)]
Iron	[Ferrous (+2)]
Iron	[Ferric (+3)]
Zinc	(+2)
Base Metals (More Anodic) (Lose Electrons)	

However, the Admiralty determined that lead sheathing was indeed detrimental to the iron fasteners, though the causes were unknown. The Milled Lead Company was unable to find a tenable solution to the corrosion problem, and was powerless to convince the Admiralty of the harmless nature of milled lead as a sheathing material. They began instead to market their product for use on the roofs of buildings.⁴² The use of milled lead as a sheathing material was discontinued by the end of the seventeenth century. Various

⁴² Hale 1695, 1.

forms of wooden planking and chemical coatings were used until the advent of a new metallic sheathing material, copper.

When problems were detected with new sheathing materials, builders tended to regress towards a previous, and often less-effective technology. There were numerous practical (and expensive) experiments with sheathing materials, with trials taking precedent over theory, which was understandable in a time when a swift solution was required to mitigate the growing damage caused by shipworms. Some of the hastily developed technologies, like milled lead sheathing, were rushed into production without extensive testing. While the long-term effects of these innovations were unknown, they would not remain so. The initial success and subsequent failure of milled lead prompted even more new innovations in sheathing materials and manufacture, but, unfortunately, the lessons learned from the abandoned technology were ignored when copper was used as an experimental sheathing material nearly a century later.

COPPER SHEATHING

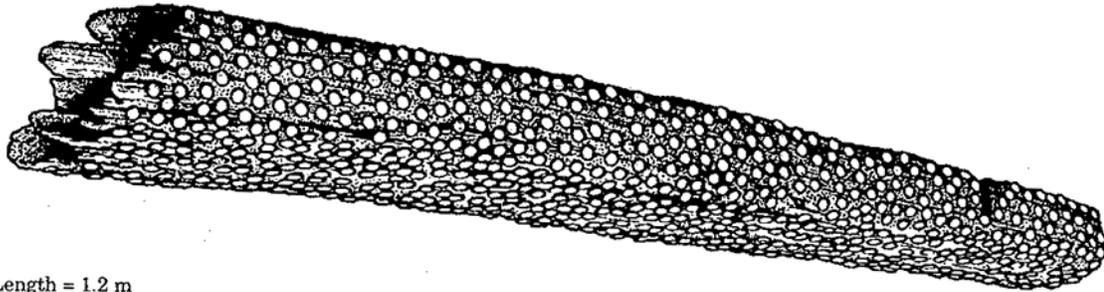
The answer to hull protection lay in copper sheathing, which was first suggested as a ship sheathing material in 1708 by Charles Parry.⁴³ However, the Royal Navy Board deemed use of pure copper too expensive and the idea was shelved. The Crown

⁴³ Knight 1976, 293.

continued covering vessels with wooden sheathing, while research into other protective materials continued.

One of these experimental methods of protecting a vessel from shipworm attack was called filling (Figure 35). Iron or copper nails with large heads were driven into a hull plank so close to each other that their heads were touching. This created a mechanical barrier of rust or corrosion product, yet the massive amount of nails needed to fill a significant portion of the hull made the treatment prohibitively expensive. This method was used sporadically through the end of the eighteenth century, and was often the only practical way to protect the false keel, where thin sheathing would be ripped off upon the slightest contact with the seafloor.⁴⁴ Wood remained the dominant method of sheathing, for the widespread acceptance and manufacture of pure copper sheathing was still a half-century away.

⁴⁴ Bingeman et al.2000, 219-220.



Length = 1.2 m

Figure 35. The false keel from *Invincible*, lost in 1758. Example of “filling” a false keel with nails to protect it from marine organisms. The nails and their corrosion products formed a physical barrier that prevented the *Teredo navalis* from boring through the wood (After Bingeman et al. 2000, 219, figure1)

The first known experiment with copper sheathing in the Royal Navy occurred in 1759, when *Panther* and *Norfolk* had their false keels clad in copper. The trial was deemed successful, and in 1761, *Alarm*, a thirty-two gun frigate, became the first Royal Navy vessel to be entirely sheathed in copper.⁴⁵ The ship was clad in extremely light 12 gauge sheathing that was fastened with copper nails.⁴⁶ After a two-year patrol through the West Indies, *Alarm* returned to England and was thoroughly inspected by the Admiralty. The results were quite satisfactory, and the Navy Board ordered several more ships to be clad in heavier copper sheathing. The use of fasteners remained problematic, as some ships were being sheathed with copper or copper alloy fasteners and others with iron. The copper fasteners experienced the least electrochemical corrosion, being closest to the sheathing composition on the electromotive force scale. The differing rates of

⁴⁵ The first American vessel sheathed with copper was the warship *Alliance* in 1781. See Laidlaw 1952, 213-214.

⁴⁶ Metallic sheathing is described by the number of ounces in a square foot of sheathing. Hence, 12 gauge means 12 ounces per square foot, and 32 gauge refers to sheathing that weighs 32 ounces per square foot.

corrosion between sheathing fastened with copper or composition alloy nails must have been noted, but there remained no standardization concerning fastener use until 1783.⁴⁷

The use of copper sheathing to protect the hulls of vessels continued to grow in the 1770s. While the copper barrier seemed to solve the problem of marine borers damaging the hull, several of the sheathed vessels experienced accelerated corrosion of iron hull fasteners, similar to what had afflicted ships sheathed with lead nearly a century before. The electrochemical corrosion occurred when the less noble iron decayed in the presence of the more noble copper, with the saltwater serving as the electrolytic solution. Since the fasteners were often in concealed places, the problem did not come to the attention of the Admiralty until a catastrophe occurred in Canada. In late 1782, several Royal Navy warships foundered in a storm off Newfoundland, sinking with an enormous loss of life. The ships' iron fasteners were said to have corroded completely, allowing the ships to fold in on themselves in the rough weather. The Admiralty ordered a temporary moratorium on sheathing new vessels until a solution to the electrochemical corrosion problem could be formulated.⁴⁸ It was eventually noticed that when the iron fasteners were insulated from the saltwater and other metals (namely the sheathing and sheathing nails), they would remain unharmed. The iron fasteners were then insulated with a variety of organic barriers, which met with some success. Thick brown paper was placed between the copper sheathing and the wooden hull planking, in an attempt isolate the

⁴⁷ Bingeman et al. 2000, 221-2.

⁴⁸ Harris 1966, 554-5.

metals from each other.⁴⁹ However, the copper nails holding the sheathing still penetrated into the hull, coming into close proximity with hull fasteners of different alloy compositions. Although the rate of corrosion was diminished, it was not eliminated. A new solution was required to eliminate the electrochemical corrosion problem between the metallic sheathing and fasteners.

Sacrificial planking could be used in lieu of thick paper to provide a barrier between the dissimilar fasteners. The thin wood planking, like that found on the Mica wreck, could also serve another purpose, namely as a spacer. By nailing the hull planks to the frames, then nailing the sacrificial planking to the hull planks, and finally nailing the sheathing to the sacrificial planking, there would be no nail holes that penetrated completely through all three layers. This arrangement would prevent leaks if the outer fasteners fell out, while preventing interior fasteners from working loose. The sacrificial planking may also have been placed on the vessel while it was being re-sheathed. In order to avoid driving sheathing nails through preexisting holes, the ship owner may have had sacrificial planking placed on the hull to give the nails a better hold. An example of sacrificial planking being applied can be seen in a contemporary photograph of a whaling ship being sheathed (Figure 36).

⁴⁹ Winfield 1997, 76.



Figure 36. Carpenters applying pine sheathing before the application of metallic sheathing (From Church 1938, Figure 17).

The copper sheets were also corroded from internal electrochemical reactions. Impurities within the copper could preferentially corrode out of the sheet, leaving it weak and porous, but at the same time, a certain amount of impurities seemed necessary to make a sheet that lasted decades instead of just a few years. George Pattison observed that even if the copper sheathing came back from a voyage clean with a light patina, the fasteners,

in this case made of an alloy containing copper, zinc and tin, would each be home to a barnacle. He described the effect “as ornamental white studs upon a green ground.”⁵⁰

The Royal Navy realized that replacing the iron bolts with copper fasteners would help mitigate the differing electromotive forces that caused the iron fasteners to corrode. However, copper bolts were too soft to be driven into the massive hardwood timbers used to frame the warships. A copper bolt had to be developed with the necessary attributes, namely hardness, to be used in place of the iron bolts. A manufacturing method, developed by William Forbes, created a hardened copper bolt that was soon used on all Royal Navy ships below the waterline.⁵¹ By 1785, the problems of electrochemical corrosion between the ship’s fasteners and the sheathing appeared to be at an end.

All of the problems associated with using copper, however, had not been solved. The copper sheathing was soft and subject to erosion, especially in areas of the ship where the saltwater sped over the surface, namely the bow. The area was sheathed with thicker copper, up to thirty-two ounces per square foot, but the friction of the saltwater proved a constant problem. A harder surface was needed, but the existing technology of hot rolling a metal destroyed some of the crystalline grain structure and its associated hardness. Yet cold rolling caused cracking, making the sheets inflexible, and impossible to fit to the compound curves of the hull. Cold rolling was more economical, because the

⁵⁰ Pattison 1829, 94.

⁵¹ Bingeman et al. 2000, 222-3.

additional steps of controlled heating and cooling of the metal were not necessary. However, it also took longer to roll the cold metal, because it was less malleable. Inventors and metal rollers continued their quest to find a metal or alloy that was malleable, yet hard, at low temperatures. With copper, they were on the right track, yet the ideal alloy and manufacturing process would continue to elude them for nearly another half century.

MIXED-METAL SHEATHING

A more durable metallic sheathing that did not damage the vessel's integrity was required. The answer was to be found in alloy sheathing, also known as composition or mixed-metal sheathing. The rapid evolution of mixed-metal sheathing occurred during the early nineteenth century. Alloys of lead, tin, copper, antimony, zinc, and mercury were created and tested. The following section provides an overview of mixed-metal sheathing development.

Zinc was considered as an alternative to copper sheathing because it was inexpensive and abundant. A patent record from 1805 relates how three inventors found the ideal combination of low heat (200-300 degrees Fahrenheit) and incremental rolling to reduce ingots of zinc into sheets of suitable gauge sheathing material.⁵² To make the sheets flexible enough to fit the curvature of a vessel, they had to be annealed (heated to a low

⁵² Honson et al. 1806, 251-2.

red heat) once more and then trimmed to size. Sheets were punched or bored (whether by hand or machine is unfortunately not specified) and then fastened with iron nails or spikes to the hull of a vessel. However, the use of pure zinc presented several problems for manufacturers desiring to use it as a sheathing material. It was prone to cracking and breaking into pieces if rolled cold, but when rolled at high heat it lost some of its desired metallurgical qualities, namely hardness and the associated durability.

The patent recommended choosing a metallic fastener that was as close to zinc as possible on the electromotive force scale, in this case, iron. Pure zinc did not have the mechanical strength to serve as a fastener. Zinc coated iron nails could also be employed to reduce the inherent galvanic corrosion caused by using dissimilar metals. While theoretically possible as a sheathing scheme, the labor and cost associated with making the composite fasteners prohibited the economic viability of zinc sheathing and fasteners. It is also necessary to note that as soon as the thin zinc plating dissolved from the iron nails, the original problem of rapid corrosion of dissimilar metals in close proximity would return.

I.R. Butts, author of a shipbuilding treatise first published in 1856, included a section on sheathing technologies. He agreed that zinc sheathing was effective for preventing shipworm attack and marine growth. Concerning its effectiveness, Butts wrote that

“Shipmasters certify that it continues as clean as yellow metal.”⁵³ Butts claimed that it lasted longer than copper and alloyed sheathing, while being considerably cheaper. However, he cited its use for sheathing ships as a recent introduction.⁵⁴ The gap Butts alluded to, between time of patent and manufacture, was almost 40 years, indicating that there was a considerable amount of time between the application for the patent, and the actual manufacture and marketing of that product.

In 1817, William Collins applied for a patent concerning the right to manufacture a new mixed-metal sheathing. The patent claimed manufacturing rights to an alloy of eighty percent copper and twenty percent tin. The bronze alloy sheathing was hailed as superior to copper, yet offered no specifics concerning durability. Collins left his patent curiously vague, stating “I do not confine myself to any precise mixture of those metals [copper and tin], or exclude any addition of other metals, or semi metals, provided the properties of the bronze metal are preserved.”⁵⁵ Collins appeared not to have had any specific knowledge of ship sheathing manufacture or metallurgy. His patent was a speculative attempt to grab a portion of the market for a product that lacked design parameters. Perhaps Collins was banking on another inventor unknowingly developing a sheathing that would infringe on his patent, in order to obtain royalties.

⁵³ Butts 1980, 145.

⁵⁴ Butts 1980, 77.

⁵⁵ Collins 1818, 67-8.

The late 1820s and early 1830s witnessed the most rapid advancements in mixed-metal sheathing technology. A range of metals and alloys were employed. The need for a durable and inexpensive sheathing was becoming more acute as naval and merchant vessels and fleets grew in size and number, sailed further, and remained away from their homeports for extended periods of time, especially whalers and explorers. By this time, *Teredo* worms, barnacles, and fouling weeds were nearly ubiquitous, being spread from their warm native waters to most of the world's temperate ports.

In 1829, American inventor John Revere developed a system of sheathing vessels with iron sheets. The iron, which would normally aggressively corrode in salt water, was preserved by the attachment of a sacrificial metal. Zinc, being less noble than iron, sacrificed electrons to the iron, preventing its decay. After two years at sea, the bottom of an iron sheathed hull was described as having a “clean, and even bright surface.”⁵⁶ There was little widespread use of iron sheathing, however, probably due to its expense and the introduction of Muntz metal several years later.

The method for sheathing a vessel in iron was identical to that for copper, with the added step of attaching a small block of zinc (five percent of the surface area of each iron sheet). The inexpensive zinc was riveted or soldered on both the internal and external surfaces of the sheet. To attach the sheathing to the hull, the patent specifies the use of iron nails with hollow domed heads, the underside of which were filled with melted tin.

⁵⁶ Pattison 1829, 94-5.

They were driven through the sheathing until they were flush with the planking, with the tin flattening out to form a washer, effectively isolating the zinc and iron. The system may have been effective, but it was considerably more labor-intensive than pure copper sheathing, and hence more expensive.

In 1830, John Gray developed a new process for mechanically punching sheets of copper, allowing the heads of the spikes to be countersunk in preformed beveled holes. The countersunk depression accepted the nail and prevented the sheet from depressing around the fastener, which would normally be left proud. When driven to the proper depth, the nail was flush with the exterior surface of the sheathing. Such a technique would make a more streamlined hull, with the surface being smooth and uninterrupted by nail heads. The machine being patented contained a template, which allowed holes to be punched at regular intervals, making the sheets identical.⁵⁷ The use of pre-punched sheathing speeded up the whole process and lessened the cost of labor for sheathing, although the manufacturer could charge more for such a convenient feature. The presence of a mechanically punched sheet of pure copper sheathing could be used as an temporal diagnostic artifact for archaeological studies.

The following year, Matthew Uzielli applied for a patent covering an alloy of one hundred parts copper and five to seven parts tin.⁵⁸ He claimed the bronze alloy had superior hardness over copper and was less prone to oxidation. To make it easier to roll,

⁵⁷ Gray 1830, 172-3.

⁵⁸ Uzielli 1831, 137-9.

Uzielli added one to two parts of lead and zinc. The alloy was smelted and then poured between two large granite slabs, which pressed the molten metal into a sheet approximately half an inch thick. The thin ingot was cut and then annealed. The ingot was heated again, cooled, and then rolled. This process was repeated twelve to fifteen times, until the sheet reached the desired thickness. The sheets were then cut or trimmed into a standard dimension. At this point the gauge or weight of the sheathing was stamped on the sheets, often near a corner.

In the same year, John Revere applied for another patent concerning an alloy that was radically different from Uzielli's creation. The alloy, ninety-five percent zinc and five percent copper, was more durable than pure zinc, and more resistant to corrosion than pure copper. There was, however, a problem in combining these two metals, as the zinc tended to combust when added to molten copper. Revere solved this problem by adding salt or pulverized charcoal to the mixture to drive off the oxygen. Without oxygen, the zinc failed to combust. With regard to the resulting brass sheathing alloy, Revere stated that, "its liability to corrode is essentially diminished."⁵⁹ He included a note in the patent that called for nails to be made from the same material. If the sheathing and fasteners used to cover a vessel were of identical composition, then the galvanic action between them would be negligible, and part of the problem with electrochemical corrosion on the vessel would be solved. However, zinc is not a hard or mechanically strong metal, and when coupled with such a small amount of copper, the alloyed material would have been

⁵⁹ Revere 1831, 29.

far too weak to be used for structural fasteners. Revere's alloy could have been used for the sheathing nails (usually one and one quarter inches in length), but the underlying problem of dissimilar metals (iron hull fasteners) in close proximity still remained. To create a barrier between the iron fasteners and the sheathing, sheets of heavy tar paper or felt were laid next to the hull, with the short sheathing nails (hopefully) not coming in contact with the iron. A layer of thin planking was also used as an alternative to paper or felt.

The use of lead as a sheathing material made one last appearance before being permanently shelved. Baron Charles Wetterstadt alloyed one hundred parts of lead and ten parts of antimony to form a harder and more durable lead sheathing. The mixed-metal was then cold rolled and painted with a molten concoction of eighty-five percent mercury, five percent antimony, and ten percent lead. The sheets were rolled once again to smooth over the finish. The result was a plated sheet of milled lead that was of a consistent thickness, flexible, and yet had a hard surface.⁶⁰ However, the sheathing was not adopted, likely because of the high cost of materials and the labor-intensive manufacturing process, not to mention the toxicity of the combined materials.

Despite the galvanic problems with the iron fasteners (bronze fasteners had not been universally adopted), copper sheathing remained the most accepted and widely used material through the middle of the nineteenth century. Nearly all of the practical

⁶⁰ Wetterstadt 1832, 411-2.

composites were more expensive in terms of materials and manufacturing cost. They offered an untested remedy to the problem of finding effective hull protection. Ship builders were unwilling to stake their reputation and livelihood on an unproven technology. Conservatism in technological adoption would be a formidable hurdle that the first successful, widely adopted mixed-metal sheathing would have to overcome.

A new mixed-metal sheathing appeared in 1832. The mixture of fifty percent copper and fifty percent zinc was patented by Birmingham industrialist George F. Muntz.⁶¹ Zinc and copper were smelted together and then rolled either hot or cold. The fact that it could be rolled without heating resulted in a significant savings in manufacturing cost. This savings, coupled with the use of a large proportion of zinc, which was considerably cheaper than copper, resulted in a relatively inexpensive sheathing. The metal's attributes included superior flexibility and surface hardness when compared to pure copper or pure zinc sheathing. Muntz's new metal was less prone to oxidation than copper or pure zinc, yet it exfoliated just enough surface scale to inhibit the attachment of barnacles and weeds.⁶² To avoid the problems associated with electrochemical corrosion, Muntz patented and produced mechanically hardened fasteners of the same composition in late 1832.⁶³

⁶¹ Muntz 1833, 195-6.

⁶² Crothers 1997, 329.

⁶³ Muntz 1834, 44-5.

The new sheathing, called 'yellow metal' because of its bright golden color, seemed ideal in every respect, yet it took more than two decades to become established. One of the difficulties plaguing Muntz was consistently mixing the exact proportions required to make the alloy. Experienced metallurgists and metal rollers were in short supply. If the new alloy varied by more than a percent from the stated proportions, its properties were radically altered. Muntz continued to develop the metal, finally settling on an alloy of sixty percent copper and forty percent zinc.⁶⁴ All of the extant Muntz metal samples tested by the author were found to contain around 62.5 percent copper and 37.5 percent zinc.⁶⁵

It was difficult to gain converts to the new sheathing technology in the early 1830s. According to a shipbuilding treaty by I.R. Butts, copper hull sheathing lasted an average of four years, zinc six, and yellow metal a mere three.⁶⁶ Muntz was forced to sell the unproven technology below cost or even give it away in order to get his product out in public view. There were also initial problems with the alloy's consistency. If two ships sailed to the same distant port, and both were sheathed in Muntz metal, one might return with bright sheathing, while the other would have corroded to the point of being useless. The sheets of both ships looked identical at the time of manufacture, but a slight difference in composition made one much more susceptible to corrosion. Despite this

⁶⁴ For a full description of the life of George Muntz and the development of his alloy, refer to Flick 1973, 70-88, and Staniforth 1985, 21-48.

⁶⁵ Appendix C contains the composition analysis of selected metallic hull sheathing samples.

⁶⁶ Butts 1980, 83.

inconsistency, Muntz's economical yellow metal slowly gained popularity through the late 1830s and 1840s, becoming nearly ubiquitous by 1855. The use of Muntz metal lasted until the advent and widespread use of iron-hulled ships. The mixed-metal sheathing continued to be used on both large and small wooden hulled vessels into the early twentieth century.

The invention and eventual successful marketing of Muntz metal did not inhibit other inventors from continuing to submit patent applications for new mixed metal concoctions. In 1835, a bronze sheathing was created in France that consisted of six to ten percent (by weight) tin added to copper.⁶⁷ The resulting bronze alloy was hard and difficult to roll, but it claimed to be twice as durable as copper while being only two-thirds as thick (the average copper sheathing or Muntz metal was 28-32 ounces per square foot, while hard bronze was 18-20 ounces per square foot). The manufacturers claimed long-term savings because of the increased durability, but ship owners were either unwilling or unable to pay the increased manufacturing expenses up front. The makers tried unsuccessfully to target the whaling industry, which required durable sheathing for their multi-year voyages. However, after 1855, the acceptance of Muntz metal was beginning to control the ship sheathing market.

⁶⁷No author 1835, 206-8.

APPLICATION OF METALLIC SHEATHING

Henry Hall, a special agent for the United States Census Office, compiled a vast report on the shipbuilding in the United States for the 10th Census in 1880. He visited many shipyards along the Eastern seaboard, and filed a report concerning the application of metallic sheathing. He noted:

The process of putting on is as follows: The bottom of the hull is first made smooth; and if it is an old vessel, the worn copper is stripped off with chisels and adzes, the sails removed, and the surface of the planking is scraped clean, the old metal and nails being sent off for sale. The hull is then either sheathed with a light planking, or is covered with cement or graved with tar and papered or felted.

Sheathing was also in vogue, and is still common; but papering or felting is the new idea, and is extensively practiced, as it is claimed that worms will not go through paper. The sheets of metal are meanwhile being prepared by punching either two, three, or four rows of holes along their edges for nailing them on. The heaviest thicknesses are put on at the bow as far back as the foremast at the load-line, but no farther aft at the keel than the forefoot. The metal of the next weight goes on aft of that, the after boundary of this thickness being a line from the mainmast at the load-line to the heel of the foremast at the keel, and grows lighter yet as the men work aft along the hull. The rudder and the keel are both covered with heavy metal. The sheets lap one inch. A bark of 310 tons requires about 1,025 sheets of metal, weighing 6,300 pounds, and 770 pounds of composition nails.⁶⁸

Hall included a table detailing the amount and gauge of metallic sheathing necessary to sheath barks and schooners of various tonnages. A 130 ton schooner, similar to the Mica shipwreck, required 90 sheets of 28 gauge, 82 sheets of 26 gauge, 100 sheets of 24 gauge, 53 sheets of 22 gauge, 97 sheets of 20 gauge and 169 sheets of 18 gauge metallic

⁶⁸ Hall 1884, 27.

sheathing. A total of 591 sheets would be required, with an aggregate weight of 1,741 kilograms (3,835 pounds).⁶⁹

Sheathing ships was a major industry in shipyards around New York. In 1884, shipwrights removed and replaced metallic sheathing on 297 vessels. The shipwrights used 135,746 kilograms (299,000 pounds) of sheathing, with large sailing ships requiring between 10442 to 11804 kilograms (23,000 to 26,000 pounds) and smaller schooners using between 2270 and 3632 kilograms (5,000 and 8,000 pounds). Hall notes that approximately half of the metallic sheathing used was of foreign manufacture, with foreign made sheathing costing 26 cents per kilogram (13 cents per pound), and American made sheathing running 32 to 34 cents per kilogram (16 to 17 cents per pound). Metallic sheathing was also used for lining the holds of grain carriers.⁷⁰

Around New York, Hall reported that ship owners purchased the required amount of sheathing and then had it punched by machine at a local shop. In Baltimore, Hall relates how a sheathing machine was used, but discontinued after the men objected to it (the reason was unspecified), and workers returned to punching the sheets by hand.⁷¹

Sheathing would typically be applied either while in dry dock, or when a vessel was hove down. Due to the chronic shortage of sheathing material in United States, ships

⁶⁹ Hall 1884, 27.

⁷⁰ Hall 1884, 118.

⁷¹ Hall 1884, 127.

would often be built and outfitted along the Eastern seaboard and then sailed to England for their sheathing. The famous USS *Constitution* was sheathed in 1795 with copper imported from England.⁷²

In the mid nineteenth century, the sheathing process began near the keel or just below the waterline. The area around the waterline was subject to increased wear from rubbing against docks, anchor lines, or other vessels, as well as being subject to the most friction from the seawater flowing past. The area was protected by thick wooden planking. The seams were caulked and then payed with tar. A layer of felt or heavy paper would then be laid down on the tar. The worn protective planking could be removed and replaced without placing the ship in a dry dock.

Metallic sheathing was applied over the bottom of the keel and then the false keel was attached and either sheathed or more likely filled or studded with nails. This was an intentional design feature. If the false keel was damaged or ripped off, the copper-sheathed keel would prevent the entrance of the marine borers.⁷³ The hull sheathing was overlapped so that, facing the bow, the leading edge of a sheet was always tucked under the one immediately forward. The standard overlap was 3-4 centimeters (1-1.5 inches) on both the horizontal and vertical axes. The amount would depend on where the sheathing began. If at the keel, then the top edge of a sheet would be tucked under the next highest layer. In areas of compound curves, sheets would be trimmed or overlapped

⁷² Laidlaw 1952, 214.

⁷³ Crothers 1997, 330.

a great deal. The latter obviously used more material, but was stronger and more durable. The most important consideration was sleekness, and, to this end, all leading edges were tucked under to avoid being ripped off during sailing.

Pure copper and Muntz metal sheathing was attached using copper alloy nails. Iron fasteners were used to hold certain types of metallic sheathing, namely lead. After being driven through the sheathing and into the planking, the iron formed a corrosion product that interlocked with the wood, enhancing the strength of the hold. Copper alloy fasteners tended to corrode lightly, and the corrosion products did not combine with the wood to grip the fastener. The copper alloy fasteners would eventually work loose. A sheathing nail advertisement from 1806 revealed how inventor Samuel Guppy modified the existing copper alloy nails to perform as well as the iron fasteners (Figure 37). The patent nails had jagged or barbed surfaces which allowed the copper alloy fasteners to tightly grip the wood and not work loose.⁷⁴

⁷⁴ Whiteman 1971, 39.

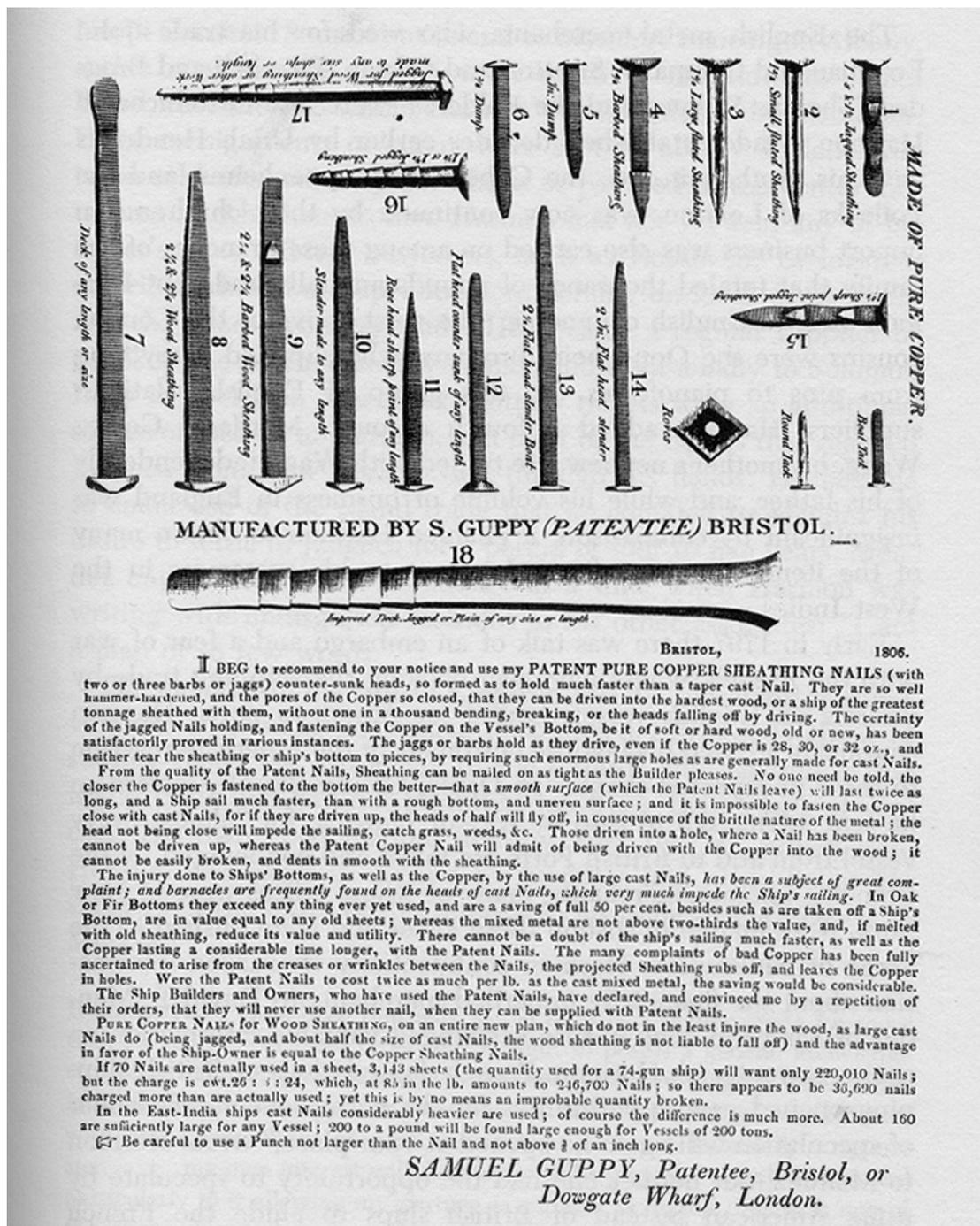


Figure 37. A sheathing nail advertisement from 1806. It revealed how inventor Samuel Guppy modified copper alloy nails to perform as well as iron fasteners (From Whiteman 1971, 39).

Besides containing details of the new sheathing nails, the Guppy advertisement listed the advantages of, and rules for, using the new hammer-hardened fasteners instead of the older, cast copper, nails. Guppy claimed that unhardened cast copper nails had an abnormally high breakage rate:

No one need be told, the closer the Copper is fastened to the bottom the better—that a smooth surface... will last twice as long , and a ship sail much faster, than with a rough bottom, and uneven surface; and it is impossible to fasten the Copper close with cast nails, for if they are driven up, the heads of half will fly off, in consequence of the brittle nature of the metal; the head not being close will impede sailing, catch grass, weeds.⁷⁵

Guppy claimed that his hammer-hardened nails had a breakage rate of one in a thousand. Even though the breakage rate seemed dubious, Guppy's nails used less metal than a comparable cast fastener and they lasted longer. He acknowledged that his nails were twice as expensive as cast nails, but argued that the investment would pay off in the long run. Guppy noted that, on average, 70 nails were used to attach each sheet of sheathing to the hull.⁷⁶ There was an average of 80 nail heads visible on each of the Mica wreck's copper sheathing sheets.

The use of cast nails created larger holes in the sheathing and planking, and, because the nails lacked barbs, they could rapidly work themselves loose, causing the sheathing to separate from the hull. Guppy continued on the detrimental effects of cast copper nails:

⁷⁵ Whiteman 1971, 39.

⁷⁶ Whiteman 1971, 39.

The injury done to ships' bottoms, as well as the copper, by the use of large cast nails, *has been the subject of great complaint; and barnacles are frequently found on the heads of each cast nail, which very much impede the ship's sailing.*"⁷⁷ [original italics]

The barnacles increased the drag of the hull, reducing the speed and handling capabilities of the vessel. Fasteners that worked loose allowed the sheet to flex. This loose sheathing fatigued the metal around each hole, eventually causing the sheet to be ripped off the hull in rough weather.

In the fastener advertisement, Guppy offered some interesting information concerning the recycling of metallic sheathing and the method of punching and applying copper sheets to the hull. When the sheathing had to be replaced, the vessel was placed in dry dock and manually stripped of all sheathing and nails. Guppy claimed that his copper fasteners could be removed and melted with the sheathing, because they were both pure copper. The cast nails, like those found on the Mica shipwreck, were a composition of copper, tin, and zinc. The cast composition nails contained up to 20 percent impurities, lessening the value of the recycled material (zinc and tin were worth less than copper). The composition nails also had to be removed by hand from the pure copper sheets before they could be melted down, with the additional labor lessening the economic incentive to recycle.

During the period of Guppy's advertisement, the early nineteenth century, sheathing a new or recently stripped hull was accomplished in the following manner: The sheets

⁷⁷ Whiteman 1971, 39.

were placed on a table and struck with a punch that was slightly smaller than the diameter of the fastener to be used. Punching the holes was necessary to avoid creating a depression by trying to force a nail through the copper sheet. The depressions, like the barnacles, decreased the sleekness of the hull. The sheet was then held against the hull, and a smaller punch was used to make a starter hole in the plank behind each hole in the copper sheet. This hole was necessary to prevent the fastener from cracking or splitting the underlying hull planking. Guppy said that the punch should penetrate no further than 1 centimeter (0.4 inches). Accordingly, the sheathing nails found on the Mica shipwreck were, on average, 3 centimeters (1.2 inches) in length. In areas of compound curves or external hull fittings, the sheathing had to be custom cut and punched.⁷⁸

THE FUTURE OF METALLIC SHEATHING RESEARCH

The study of the development of mixed-metal sheathing technology has provided archaeologists and historians with another diagnostic tool for dating shipwrecks. When a piece of sheathing is recovered, composition analysis can be performed that gives the exact amounts of the constituent elements. The accuracy of the composition tests, coupled with analysis of the metallic grain structure, can create a sort of fingerprint for each sheathing sample. The fingerprints can be used to identify two ships that were sheathed from the same lot of metal or even identify differences in sheathing origin across the hull of a single vessel. Gauge analysis can reveal patterns of thickness and

⁷⁸ Whiteman 1971, 39.

identify areas where the sheathing was subject to accelerated corrosion or erosion. The fingerprints can also be compared to patent records or other known examples from precisely dated shipwrecks. It is possible to look at the fastening pattern and determine whether the sheathing was applied before or after the advent of mechanical punching. The fasteners themselves can be diagnostic. Manufacturers often stamped the heads of large nails and bolts with their company name or the patent date. Information concerning sheathing technology has been used to help identify and date several shipwrecks, and it is hoped that the trend will continue. Metallic sheathing is a complex artifact that, with continued research, will offer much new information to nautical archaeologists.

CHAPTER V

THE MICA VESSEL: A HYPOTHETICAL SAILING RIG

The Mica shipwreck field investigation provided relatively little direct evidence concerning the design, construction, and rig of the vessel. However, as a research exercise the scant archaeological evidence could be combined with historical data to construct a hypothetical sailing rig. The fact that the small vessel was sheathed with expensive copper suggests that it was worth sheathing, meaning that it was well built. The fine lines and fast hull created by the metallic sheathing would best be complemented by a schooner rig. The following hypothetical rigging reconstruction offers a possible example of what the Mica vessel might have looked like and how it might have been rigged. The example should not be taken as fact, but should hopefully serve as a foundation for future research on the Mica shipwreck.

The following chapter outlines the methods undertaken during the Mica shipwreck rigging reconstruction. Contemporary sources were researched and analyzed to determine a plausible design and rig for a fast sailing coastal merchant schooner in the early nineteenth century. The vessel was reconstructed using the hull profile of the contemporary merchant schooner *Glasgow* (Figure 38). The accompanying drawing shows the masts, spars, running rigging and standing rigging. The chapter also provides justifications for the rigging choices depicted in the drawing.

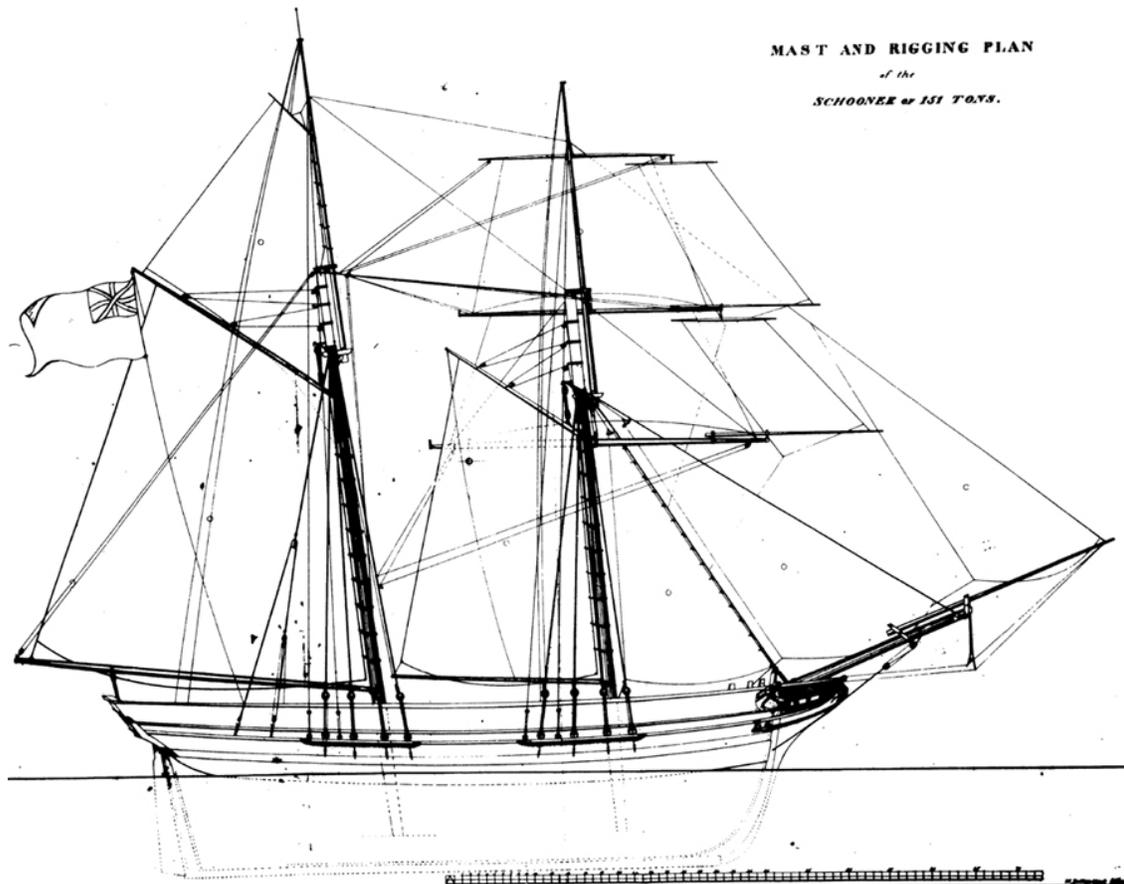


Figure 38. Peter Hedderwick's 1826 rigging plan for *Glasgow*, a schooner of 151 tons (From MacGregor 1997, 39).

Armed with information about vessel dimensions, probable vessel origin and rig type, it was possible to reconstruct the ship's rig by utilizing contemporary sources on early nineteenth-century merchant schooner rigging and ship construction. The sources included photographs of aging schooners taken in the mid-nineteenth century, drawings and paintings of schooners, and contemporary tables of salient ship rigging dimensions and marine architecture treatises.

Secondary sources were useful because they reprinted photographs and plates from rare works, as was the case with the Peter Hedderwick treatise on marine architecture. The Hedderwick treatise, reprinted in part in a recent work by David R. MacGregor, provided useful information concerning the merchant schooner *Glasgow* of 151 tons that was built in 1826.⁷⁹ The vessel, a two-masted topsail schooner, had a length on deck of 21.9 meters (72 feet) and a length on the keel of 20.5 meters (67 feet), exactly matching the length dimensions of the Mica shipwreck. The *Glasgow* hull form, with its full entrance and extremely narrow run, provided an excellent fit with the extant Mica hull. For those reasons, the merchant schooner depicted on plate XXVI of Hedderwick's treatise was chosen to be the hull form of the Mica vessel rigging reconstruction.⁸⁰

Because no rigging elements, with the exception of two sets of chainplates, were identified during the investigation of the Mica wreck, the placement of these elements, as well as their dimensions, was a matter of informed conjecture. The location of the chainplates was documented by an archaeologist during a visit to the site in the submarine *NR-1*. Photographic images were the primary source of rigging element dimensions and their placement. Three photographs of representative examples of contemporary fore-and-aft rigged schooners were used during the rigging reconstruction process. They included *Polly*, a two-masted schooner built in Amesbury, Pennsylvania in 1805, *Hope*, a two-masted schooner built in Bideford, England, in 1849, and an aging unidentified schooner photographed in Havana in 1860 (Figures 39, 40 and 41).

⁷⁹ MacGregor 1997, 37-40.

⁸⁰ MacGregor 1997, 39.

Dimensions were scaled off of the photographs by basing the scale on the height of a person at six feet.

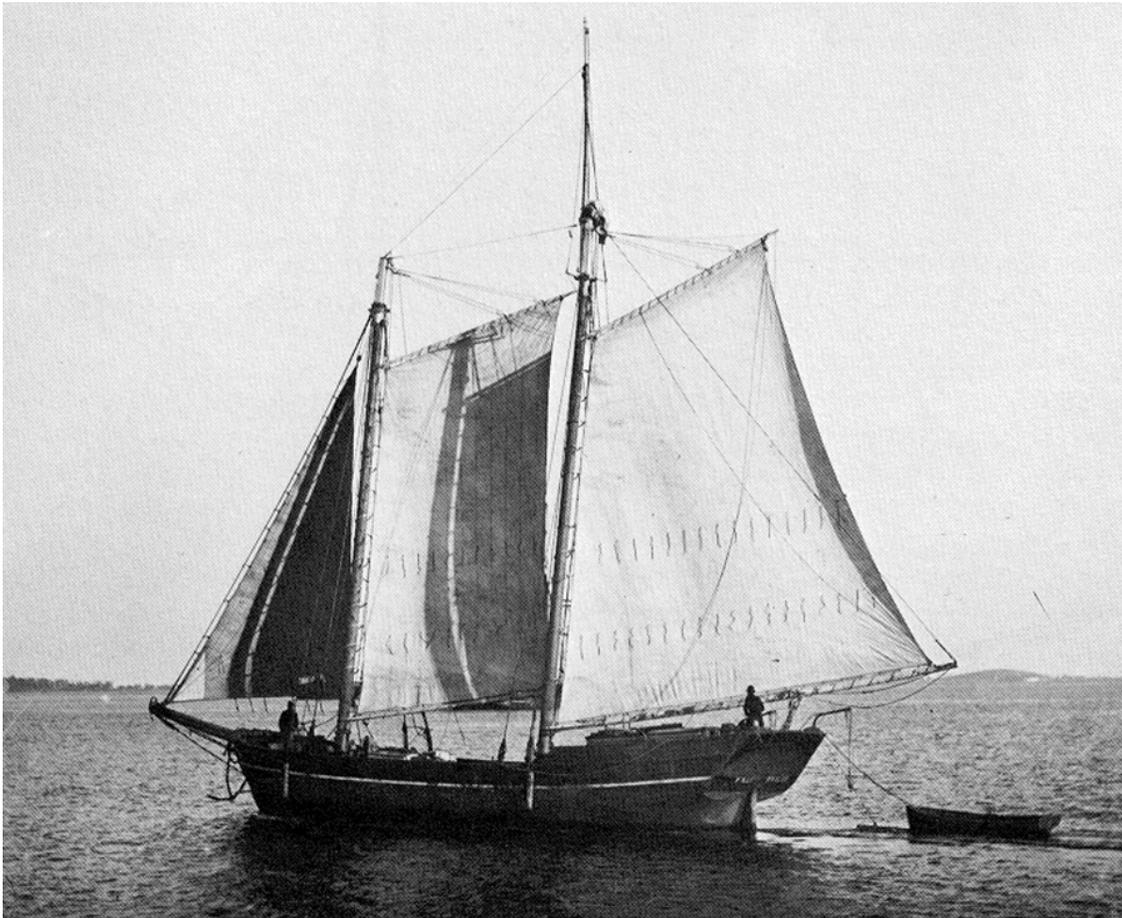


Figure 39. The gaff rigged schooner *Polly*. Built in 1805 in Amesbury, Pennsylvania, and later rebuilt in 1861 (From MacGregor 1982, 55).



Figure 40. The two-masted fore-and-aft rigged merchant schooner *Hope*. The vessel is shown with double topsails and no studding sail (From MacGregor 1997, 67).

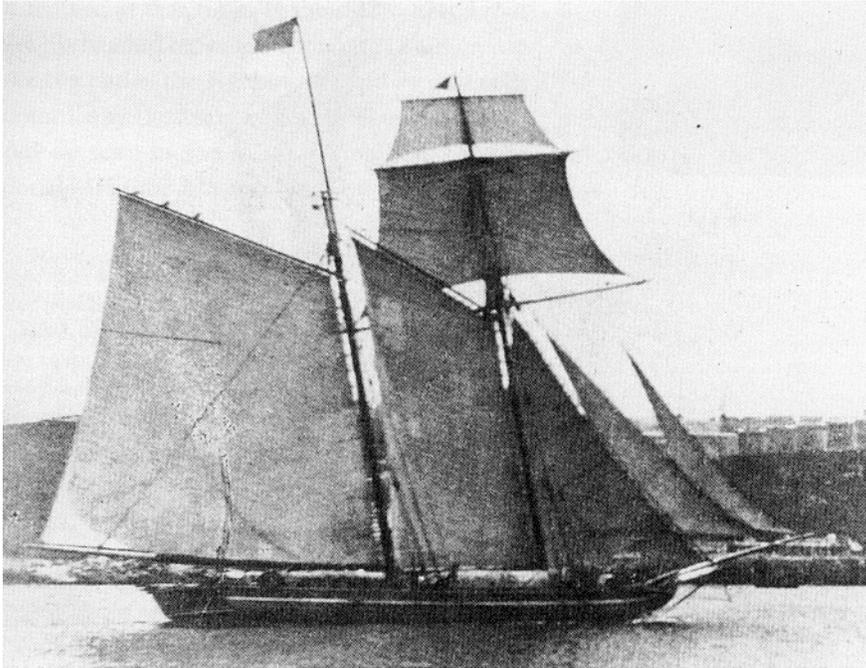


Figure 41. An aging unidentified two-masted topsail schooner. The vessel, showing a top gallant sail, was photographed in the Havana harbor in 1860 (From MacGregor 1997, 33).

The photographs were compared to several building plans of merchant schooners, including Hedderwick's *Glasgow*, an original builder's plan of the schooner *Elizabeth Austen*, and a lines drawing of the HMS *Subtle*, an American-built, Danish-owned schooner captured by the British in 1808 and pressed into naval service as an armed schooner (Figures 42 and 43). *Subtle* was lost in a violent squall while pursuing an

American privateer in the West Indies in 1812. Chapelle, who drew the lines and recorded a table of *Subtle's* mast and spar dimensions, failed to cite his original sources.⁸¹

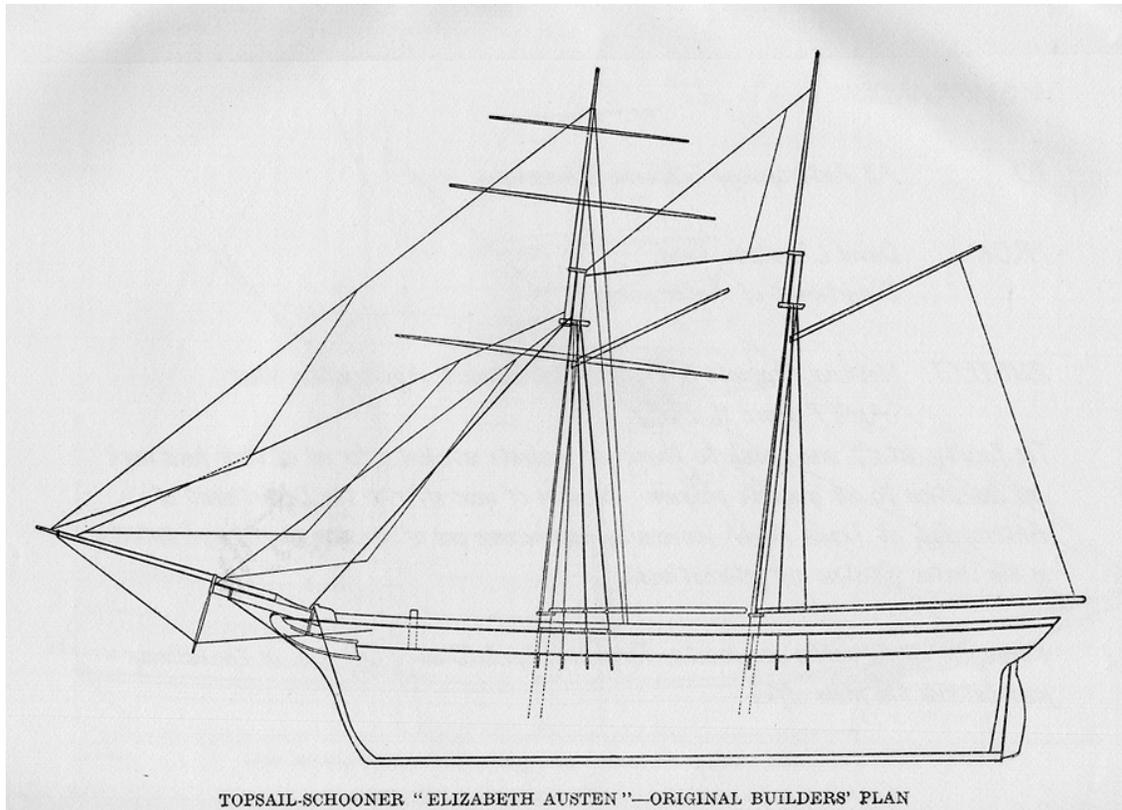


Figure 42. Original builder's plans for the topsail schooner *Elizabeth Austen*, (After Underhill 1952 Plate 18).

⁸¹ Chapelle 1935, 234.

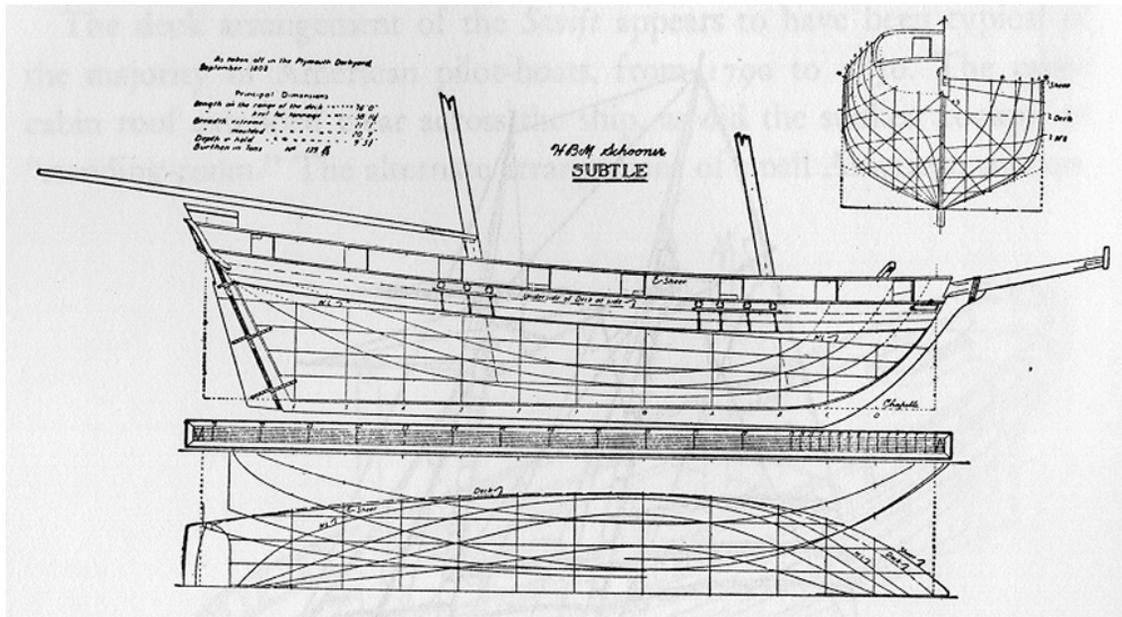


Figure 43. Lines of HMS *Subtle*, lost in a violent squall while pursuing an American privateer in the West Indies in 1812 (From Chapelle 1935, 232).

All six representations of nineteenth-century merchant schooners were analyzed and averaged to create a plausible rigging reconstruction to place on Hedderwick's *Glasgow* hull (Figure 44). Therefore, the Mica shipwreck rigging reconstruction did not exactly resemble any single source, but rather, was a sum of its parts, a hypothetical hybrid two-masted fore-and-aft rigged schooner of the type that would have been common along the coast and in the ports of the early American republic.

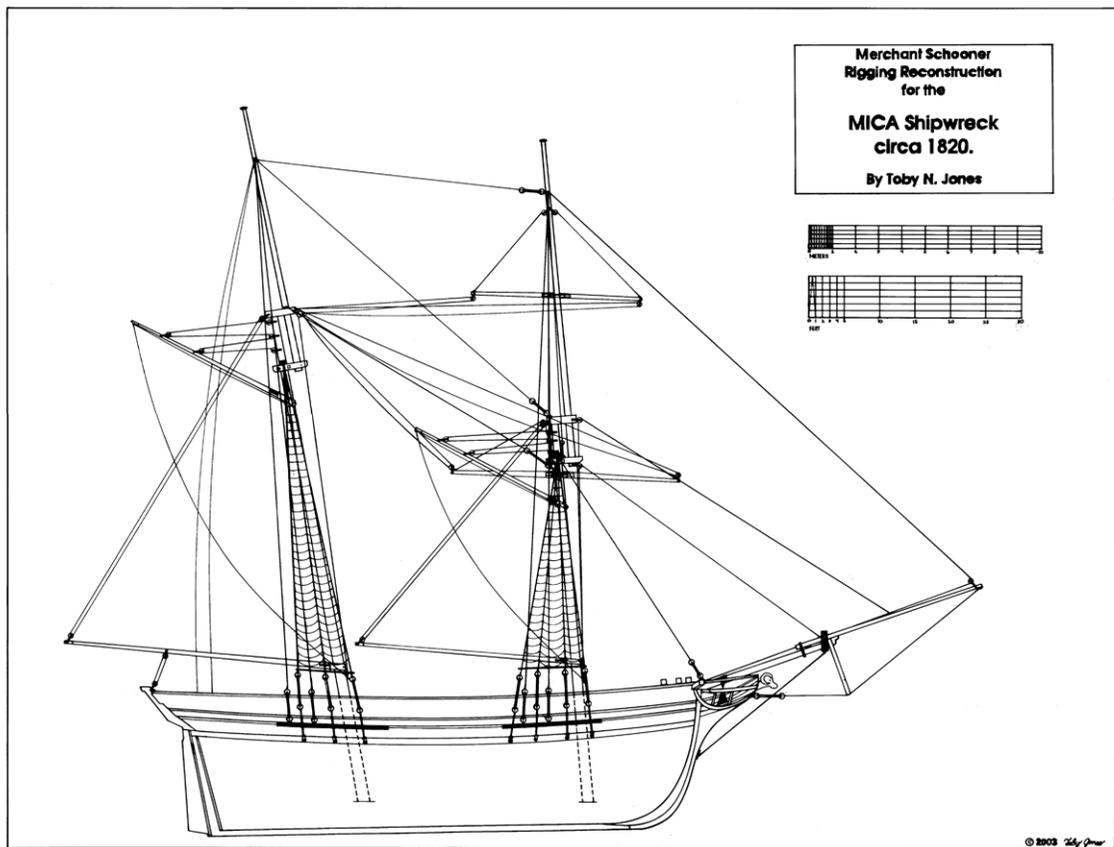


Figure 44. Hypothetical Mica shipwreck rigging reconstruction (Drawing by author).

The following section includes specific details relating to the reconstruction of the vessel. The hull selection has already been discussed above, so the next logical areas to explore were the dimensions of the vessel's masts and spars, followed by the standing and running rigging, and concluding with the sail plan and sailing performance considerations.

MASTS

The Mica shipwreck rigging reconstruction was a two-masted fore-and-aft rigged merchant schooner, and by definition, it had a foremast and a mainmast. Both masts had topmasts, but only the foremast carried a topsail. The diameter, dimensions and placement of the masts was determined by averaging the dimensions visible in the photographs and builder's plans. The foremast was an average of 19.7 meters (54 feet) in height, when measured from the keelson, while the mainmast measured 25.9 meters (71 feet) in height, also measured from the keelson. The fore topmast averaged 16.8 meters (46 feet) in length, while the main topmast was 13.0 meters (38 feet) in length. The diameter of both the fore topmast and main topmast was calculated to be 0.4 meters (1 foot), with both tapering upward to a minimum of 0.17 meters (0.58 feet) in diameter.

The doubling was averaged, with the foremast having 2.1 meters (7 feet) of it, while the mainmast had 2.7 meters (9 feet). The foremast diameter was an average of 0.5 meters (1.6 feet) at the deck, while the mainmast has a diameter at the deck of 0.51 meters (1.7

feet). Chapelle listed the *Subtle* as having a mainmast diameter of 0.44 meters (1.45 feet) at the deck, while the foremast had a diameter of 0.45 meters (1.48 feet) at the deck.⁸² The similarity of the mast diameters is reflected in the nearly identical diameter of both lower masts on the Mica reconstruction. The foremast entered the deck 4.9 meters (16 feet) abaft of the stem, while the main mast entering 13.1 meters (43 feet) abaft of the stem. The forward set of chainplates seen on the Mica shipwreck were located 5 meters (16.4 feet) abaft of the stem. The forward most chainplate would have been even with or slightly forward of the front face of the foremast.

The rake of the masts was established by averaging the rake of *Glasgow*, *Polly*, *Hope*, *Elizabeth Austen* and *Subtle*. The foremast averaged five degrees of aft rake, while the mainmast had 10 degrees. The average rakes were incorporated in the drawing. The mast taper for the main, fore, and topmasts were determined by measuring the widths of the masts at the deck, below the cap, above the cap and below the signal pole or mast head on all the representations where the diameter was visible. The mast caps, trestle trees, and cross trees were scaled off Hedderwick's *Glasgow* building plan.⁸³

The bowsprit and jib boom measurements were arrived at in a similar fashion. The bowsprit had a diameter of 0.56 meters (1.83 feet), while the jib boom had a diameter of (0.25 meters) 0.83 feet). The angle or steeve of the bowsprit projection was averaged from several photographs and drawings, and determined to be 18 degrees above the

⁸² Chapelle 1935, 234.

⁸³ MacGregor 1997, 39.

horizontal plane. The bowsprit protruded an average of 6.1 meters (20 feet) from the stem, while the jib boom had an overall length of 8.53 meters (28 feet). The doubling was estimated to be 1.21 meters (4.0 feet). The dolphin striker, which extended at a right angle from the jib boom on five out of the six representations (the *Glasgow's* bowsprit being the exception, pointed straight down) was calculated to be 2.6 meters (8.5 feet) long, with a hanging knee or carrier brace placed on the forward face.

SPARS

The fore-and-aft rigged Mica shipwreck reconstruction carried a large square sail on the foremast, which provided additional sail area to propel the sleek hypothetical vessel even faster. The lower yard was slung from the foremast, while the fore topsail yard was slung from the fore topmast. The fore topsail was thus anchored to the lower foremast, a practical solution that directed the majority of the strain from the large sail into the thicker lower mast. The dimensions and placement of the yards was determined in the same way as that of the masts discussed above. The dimensions were scaled off of the photographs and builder's plans, calculated and then averaged. The lower yard was an average of 9.8 meters (32 feet) in length, while the topsail yard was 7.3 meters (24 feet) in length. The top edge of the foremast yard was slung just below the doubling, 11.0 meters (36 feet) above the deck. The top edge of the fore topsail yard was slung 18.6 meters (61 feet) above the deck. The lower yard had a maximum diameter of 0.25 meters (0.83 feet), while the upper yard had a maximum diameter of 0.20 meters (0.7 feet).

Both yards had an even taper towards the yardarms, and were attached to the mast with rope lashings and cleats. Both of the yards were controlled by braces, which are discussed below.

The primary sail on the foremast was the large fore-and-aft gaff sail. The boom was 9.8 meters (32 feet) in length, from the tip of the boom to the tip of the jaws. The diameter of the boom was 0.25 meters (0.83 feet), just abaft of the throat. The fore boom has an angle of 80 degrees, if the mast was set horizontal at zero degrees. The fore gaff was an average of 7.3 meters (24 feet) in length from tip to jaw, and had a diameter of 0.25 meters (0.83 feet) abaft the throat. The foresail gaff came off the foremast at an angle of 57 degrees. The center of the boom was located 2.4 meters (8 feet) above the deck, while the foresail gaff was located 9.1 meters (30 feet) above the deck.

The main mast carried a single large fore-and-aft sail. The boom measured 12.2 meters (40 feet) in length, with a diameter of 0.30 meters (1 foot) abaft the throat. The boom left the mast at an angle of 75 degrees, if the mast was set horizontal at zero degrees. The top of the main boom was set 2.7 meters (9.0 feet) above the deck. The top of the main gaff was set 13.7 meters (45 feet) above the deck, at an angle of 53 degrees. It had a length of 7.9 meters (26 feet) and a maximum diameter of 0.25 meters (0.83 feet).

STANDING RIGGING

The standing rigging of the Mica ship reconstruction was relatively simple. It consisted of forestays, shrouds, backstays, a bobstay and a martingale stay. Analyzing and comparing the photographs of contemporary vessels helped determine the correct placement of the rigging. The builder's plans of similar vessels and a little common sense regarding ship rigging were also employed.

The dolphin striker provided a fulcrum point that allowed the martingale to pull down on the jib boom with enough force to counteract the strong upward pull of the foremast forestays. The bobstay, as well as the gammoning of the bowsprit to the knee of the head provided additional support to the bowsprit and jib boom. The jib boom was attached to the bowsprit where it ran through the bowsprit cap, and was supported by the jib boom saddle that was abaft the cap, as well as a clamp abaft the chock (Figure 45).

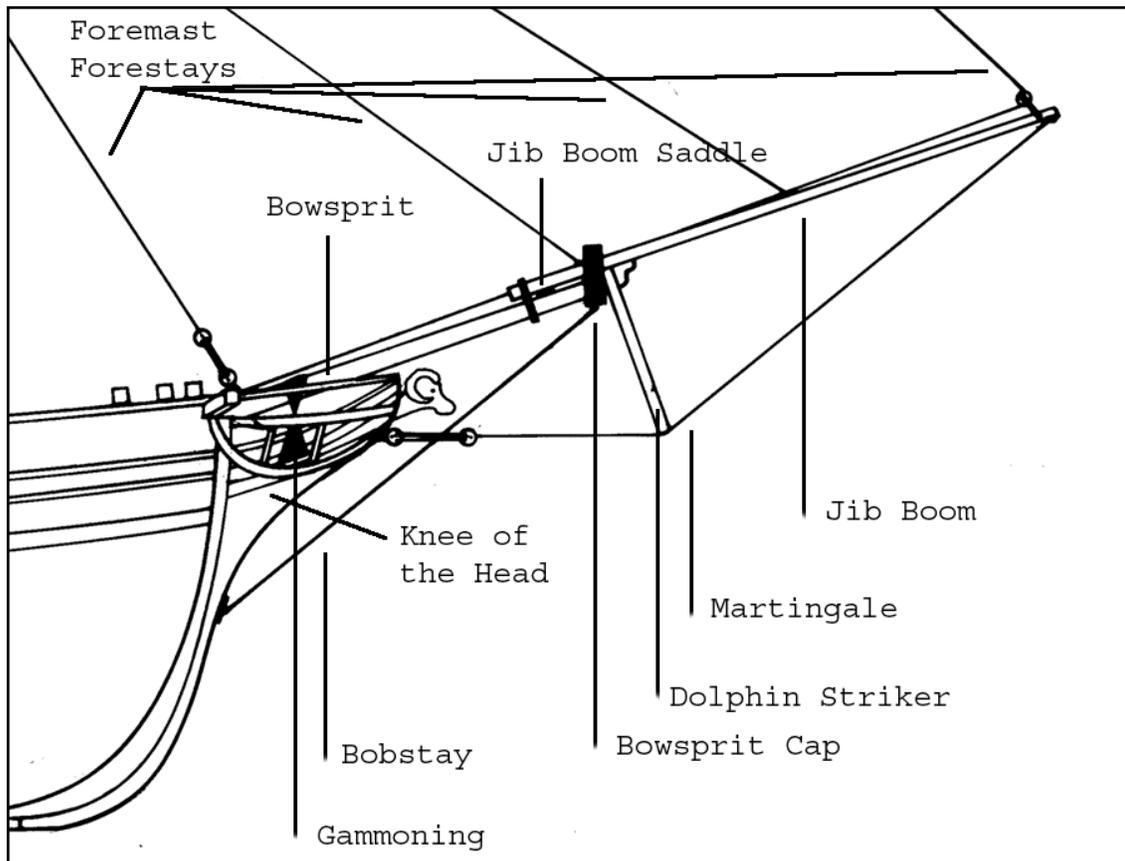


Figure 45. Selected bow area nomenclature (Drawing by author).

There were four forestays on the foremast. The fore topmast forestay was anchored to the fore topmast and ran through a block attached near the end of the jib boom. That line ran aft along the bowsprit before entering the hull, where it was secured to a set of deadeyes. The next lower stay, the outer jib stay, was anchored to the jib boom and ran up and aft, where it ran through a block fastened to the forward edge of the foremast cap. That line ran down to a cleat on the forward edge of the foremast, where it was tied off.

The next lower stay, the inner jib stay, ran in the same direction, through a block on the forward crosstree on the foremast. That stay was anchored abaft the bowsprit cap.

The foremast forestay was attached to the foremast immediately above the crosstrees and trestletrees. That stay ran forward and down, and was anchored to a set of deadeyes attached to the top of the stem. The forestays for the mainmast and main topmast ran forward to the foremast. The forestay on the main topmast ran forward and down to a set of deadeyes attached to the after edge of the foremast cap. The mainmast forestay ran forward and down to a set of deadeyes attached to the after crosstree on the foremast.

In the reconstruction, four shrouds were placed on each side of the foremast, and two shrouds on each side of the fore topmast (Figure 46). The remains of two sets of deadeyes and chainplates were seen in both the starboard bow quarter and port stern quarter of the Mica wreck. This was taken as a minimum number, with the likelihood that additional elements were missing or buried under the sediment inside the wreck. A comparison of the contemporary photographs and Hedderwick's treatise show the vessels rigged with 3-4 chainplates and deadeyes per side on the fore and main masts. The reconstructed mainmast had three shrouds on either side of the mast. Both sets of lower shrouds looped around the lower masts and were spliced to themselves, just above the crosstrees and trestletrees. According to Biddlecombe, the shrouds were 0.13 meters

(0.44 feet) in circumference.⁸⁴ All the shrouds ran from the mast down to deadeyes attached to chainwales. The deadeyes were 0.25 meters (0.83 feet) in diameter, which was half of the diameter of the mast which they were serving, a rule cited by R.C. Anderson.⁸⁵

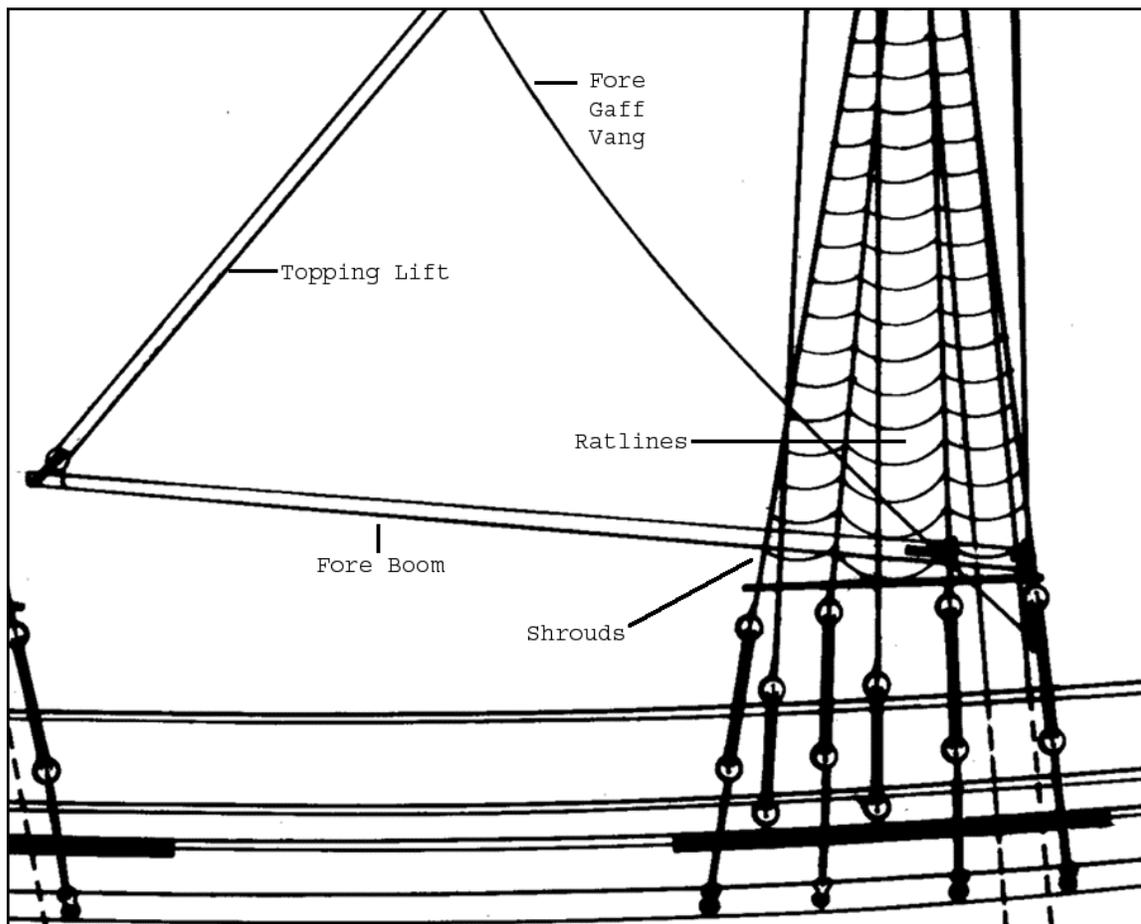


Figure 46. Lower forward rigging nomenclature (Drawing by author).

⁸⁴ Biddlecombe 1990, 150.

⁸⁵ Anderson 1982, 93.

The fore topmast was supported by two shrouds on either side, which were attached to deadeyes that were anchored through the outer ends of the crosstrees. According to Biddlecombe, a merchant schooner of between 100 and 200 tons would have topmast shrouds that were 0.07 meters (0.23 feet) in circumference.⁸⁶

The deadeyes for each shroud were spaced 1.75 meters (5.75 feet) apart. The dimensions were taken from Hedderwick's *Glasgow* building plan, because the deadeyes were clearly depicted. This amount of spacing would vary depending upon the lengths of the shrouds, which were probably only consistent to a general degree. Ratlines were placed on the foremast and mainmast shrouds, with a vertical spacing of 0.36 meters (1.2 feet). The ratlines began just above the pine sheer batten, which prevented the deadeyes from twisting. It should be noted that the ratlines would probably have been tauter in reality than were depicted in the Mica shipwreck rigging reconstruction drawing.

The main boom was secured downward with a main sheet and tackle to an iron staple or 'sheet horse' in the deck. Two backstays were placed on each side of the fore topmast and main topmast and ran down and aft to the aft part of the chainwales, where they were attached to deadeyes. The deadeyes were identical to those employed by the lower masts (Figure 47).

⁸⁶ Biddlecombe 1990, 150.

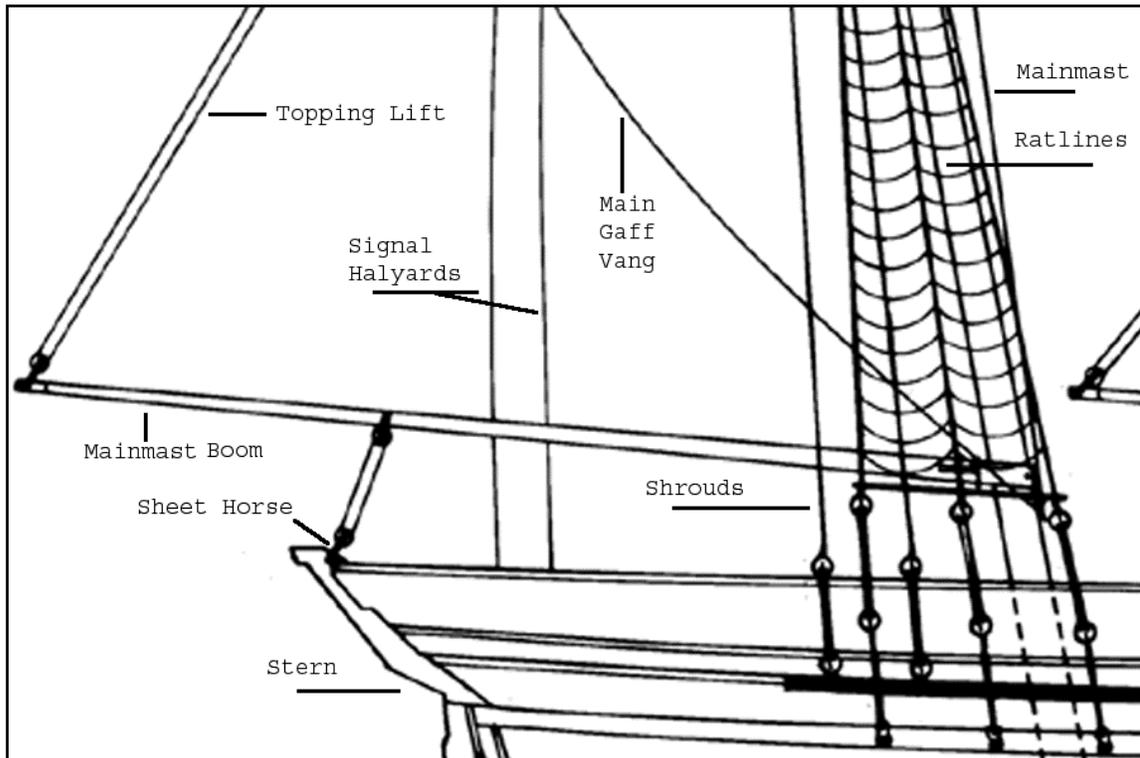


Figure 47. Lower aft rigging nomenclature (Drawing by author).

The mainmast had three forestays running forward to the foremast. Two of the mainmast forestays ran from near the top of the main topmast forward, and attached near the top and bottom of the fore topmast. The third forestay ran from the forward edge of the mainmast cap forward to a deadeye anchored immediately beneath the aft crossree on the foremast.

A note on the shroud placement is in order. The forward most shroud on both the foremast and mainmast was placed slightly forward of the plane of the mast itself. This feature only appeared clearly on Hedderwick's *Glasgow*. The other schooner

representations showed the forward-most shroud on each mast being even with the forward edge of the mast. To be consistent with the averaging of features that form the foundation of this reconstruction, the shrouds should have been drawn as represented in the photographs, not the builder's plan.

RUNNING RIGGING

The running rigging controlled the sail and spar adjustment, and, on the Mica shipwreck rigging reconstruction, consisted of topping lifts, peak and throat halyards, vang and braces. Much of the rigging information was derived from Hedderwick's building plan, although all the images were utilized in some fashion. The topping lifts were clearly represented in several of the photographs, and their attachment points and dimensions were scaled, averaged and applied to the reconstruction. The circumference of the topping lifts, according to Biddlecombe's rigging table for schooners between 120 and 130 tons, was 0.08 meters (0.25 feet).⁸⁷ Both the fore boom and main boom were depicted as having topping lifts. However, evidence of this was not visible in the photographs. It was assumed that this extra support on the fore boom would be necessary given the length of the boom and the total sail area. If it were not deemed necessary by the ship operator, it could have been removed. However, while installed, it would not detract from the sailing ability of the vessel, and would add an extra measure of support to the fore boom element.

⁸⁷ Biddlecombe 1990, 151.

The peak and throat halyards for the fore and main gaffs were visible on *Glasgow*, *Polly*, and *Hope*. All of the halyards had similar placement and size. The *Glasgow* and the *Hope* had three blocks on the mast, while the *Polly* only showed two. Given the large size of the gaffs on the Mica reconstruction, three halyard blocks were chosen to support the gaff on both the fore and main masts. The lines running through these blocks were 0.08 meters (0.25 feet) in circumference on both gaff sails (Figure 48).⁸⁸

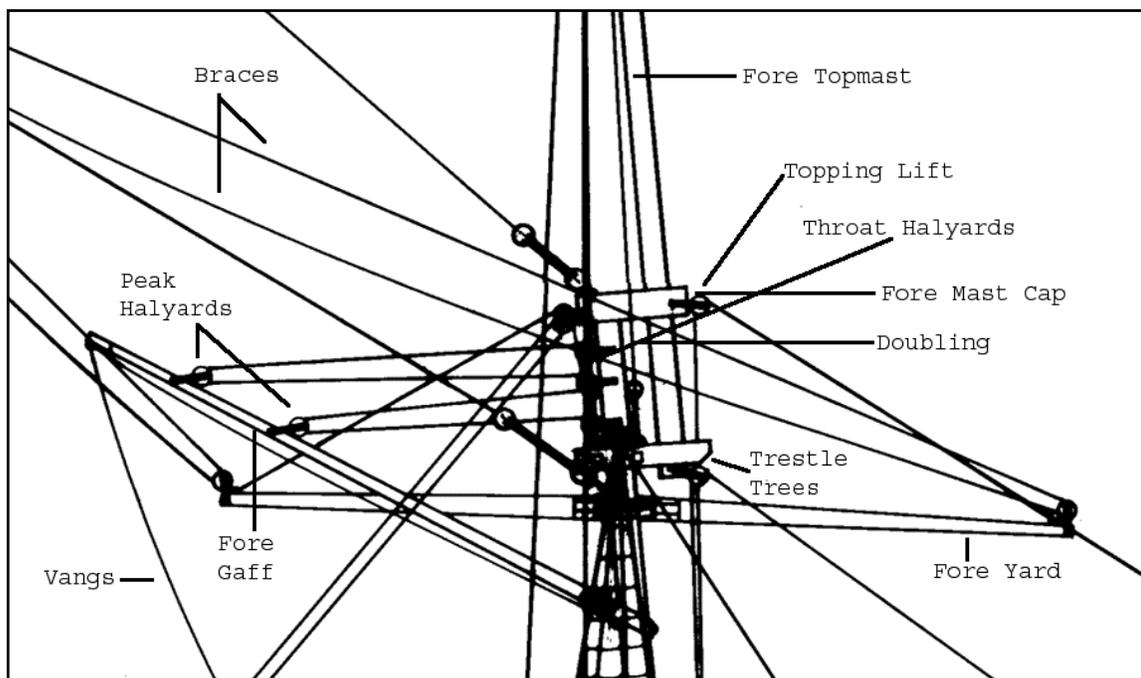


Figure 48. Upper forward rigging nomenclature (Drawing by author).

⁸⁸ Biddlecombe 1990, 151.

Vangs were visible on the *Glasgow*, *Hope*, *Polly*, and on an unidentified schooner moored in Havana. The vangs were used for manipulating the gaff towards the port or starboard. All of the images showed the vangs attached near the after end of the gaff on both the main gaff and fore gaff. The vangs hung slack and trail forward and down, where they are tied off to a cleat on the forward face of their respective masts. Two signal halyards were placed aft of the mainmast, and ran from the gunwale to the head of the main topmast (Figure 49).

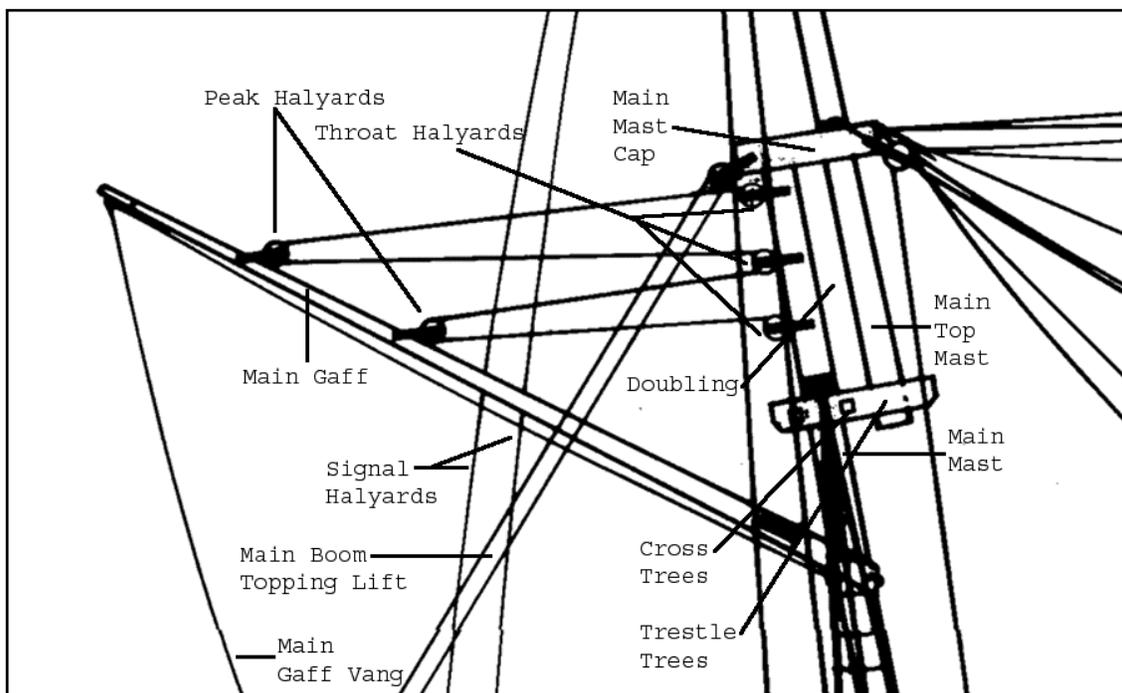


Figure 49. Upper aft rigging nomenclature (Drawing by author).

There were four braces shown on the Mica shipwreck rigging reconstruction. They all trailed aft from the fore topsail yard and the foresail yard. The braces for each yard ran

through a double block attached to the forward edge of the mainmast cap. From there, the lines ran down to cleats on the forward edge of the mainmast. Biddlecombe stated that all of the braces on a merchant schooner of this size were 0.04 meters (0.15 feet) in circumference.⁸⁹

SAILS

There were seven sails that the reconstructed Mica wreck vessel could have set. The flying jib stretched along the fore topmast stay, between the fore topmast and the jib boom. Another jib sail was set along the outer jib stay, running from the forward edge of the foremast cap toward the center of the jib boom. The third jib sail was set on the inner jib stay, and ran from the forward edge of the forward crosstree toward the aft edge of the bowsprit mast cap. A staysail was set on the foremast forestay, running from the foremast, immediately above the crosstrees and trestletrees, to the top of the stem.

The foremast carried a fore-and-aft sail, and a large square sail hung from a fore topmast yard and a larger yard placed just below the doubling on the foremast. The mainmast carried a large fore-and-aft sail. Other sails could have plausibly been added to the Mica shipwreck vessel reconstruction plan. These included a triangular gaff topsail on the main topmast, and possibly a double topsail or a topsail and topgallant sail on the fore

⁸⁹ Biddlecombe 1990, 149.

topmast. Both were commonly seen on merchant schooners during the first half of the nineteenth century.

CONCLUSION

The reconstruction of the Mica shipwreck's rig produced a generalized mast, rigging, and sail plan for an early nineteenth-century two-masted merchant schooner. Such schooners were ubiquitous along the coasts of North America, and were probably rigged with a multitude of variations. It is important to remember that there were no hard and fast laws concerning the way to rig a ship. Functional considerations, practicality and common sense were the guiding principles when building a sailing rig. Economy and safety were continually at odds, with ship operators trying to sail with a minimum crew and maximum amount of cargo. The operators of the fast-sailing metallic-sheathed Mica vessel likely analyzed that balance, and were continually looking for ways to improve economic efficiency.

CHAPTER VI

CONCLUSIONS

Based on the dimensions, vessel form, and construction style and material, it is probable that the Mica vessel was a fine-lined example of the ubiquitous merchant schooner that sailed to and from coastal ports in the early nineteenth century. Historical sources relating specifically to the loss of the Mica shipwreck have yet to be found. The original name of the vessel remains unknown. Without a name, it is possible only to generalize about the role of the Mica vessel in the seafaring history of the Gulf of Mexico. A review of the ship enrollment records, from New Orleans, Louisiana, has yielded hundreds of vessels that fit the dimensions of the Mica wreck. While occasionally containing information on the ultimate fates of the enrolled vessels, the records do not provide enough information to reconcile a name with the Mica shipwreck. As such, it is impossible to determine how many, if any, casualties were caused by its sinking. Given its distance offshore, it is possible that the vessel was lost in a storm with no survivors. The wreck site is far enough from land that the vessel may have slipped under the waves with no witnesses and no record of its loss.

Certain aspects of the shipwreck continue to puzzle nautical archaeologists. The reasons why copper sheathing was placed over a layer of sacrificial wood planking remain unknown. The corrosive effects of dissimilar metals in close proximity were known by

this time, and it appeared that the Mica vessel had copper alloy keelson bolts and rudder hardware. If the structural fasteners were copper alloy, and the sheathing and associated fasteners were copper and copper alloy, respectively, then the problem of electrochemical corrosion would be minimal, and a layer of wood between the sheathing and the main hull would be unnecessary. The copper sheathing may have been applied over the original sacrificial planking some time after the vessel was constructed. The life of the Mica vessel may have spanned the time between the use of wood sheathing and the widespread use of copper. The expensive metallic hull protection likely made the vessel sail faster and required less regular hull maintenance. Yet, it was unusual to find merchant vessels with copper sheathing during the late eighteenth and early nineteenth centuries.⁹⁰

The presence of copper sheathing hints that the ship served a specialized purpose, such as a slaver, smuggler, or a vessel that carried valuable time-sensitive cargo, like fresh fruit or fish. To recoup the large initial financial outlay to sheathe the vessel, and make a profit, the ship operator had to select one of these value-dense cargoes. The sail area would have to be maximized on such a vessel to increase speed. However, the final cargo that the Mica vessel carried remains a mystery. The investigators were unable to take any sediment cores for palynological analysis. Initial reports stating that the wood samples, retrieved during at the time of discovery, showed evidence of charring remain unsubstantiated, as the specimens were consumed during identification testing.

⁹⁰ Childers 1970, 41.

THE FUTURE OF DEEPWATER NAUTICAL ARCHAEOLOGICAL RESEARCH

To date, the Mica investigation represents the deepest archaeologically-oriented study of a shipwreck in the Gulf of Mexico. It was made possible by a cooperative agreement between the several federal agencies, the military, institutions of higher education, and the private sector. Such a multi-disciplined approach supplied the research team with the expertise and equipment necessary to successfully complete the project. The confluence of technology, expertise and interest created the necessary climate to proceed with the investigation. The data gathered about the Mica shipwreck was as important as the deepwater nautical archaeological research methods that were formulated and tested during the mission. The team learned equally from the successes and failures of the undertaking. The objectives of the project, to study the shipwreck and test new investigative methods were largely satisfied. More reliable and capable equipment will be necessary to conduct effective research at ever increasing depths. Specific examples of the technology include remotely operated vehicles, both tethered and autonomous, that are capable of sending real-time high-resolution digital video images to archaeologists on board the surface support vessel. In addition to the “eyes” at the site, researchers need tools that can sample and remove the overburden in a controlled fashion. Manipulators with soft grip jaws will be necessary to pick up unconsolidated ferrous artifacts as well as delicate ceramics. High resolution remote sensing equipment with low operating costs will become a necessity to survey large areas of the deep ocean. The future of deepwater nautical archaeology will remain bright as long as technological

development continues to provide researchers with an effective presence at an otherwise inaccessible site.

WORKS CITED

- Anderson, R.C. 1982. Reprint. *The Rigging of Ships in the Days of the Sprintsail Topmast: 1600-1720*. Centreville, Maryland: Cornell Maritime Press. Original edition: publisher not listed, 1927.
- Biddlecombe, George. 1990. Reprint. *The Art of Rigging*. New York: Edward W. Sweetman Company. Original edition, Salem, Massachusetts: Marine Research Society, publication no. 8. 1925. (Developed from *The Elements and Practice of Rigging and Seamanship*, by David Steel, London, 1794).
- Bingeman, J., J. Bethell, P. Goodwin, and A. Mack. 2000. "Copper and Other Sheathing in the Royal Navy." *International Journal of Nautical Archaeology* 29.2: 219-220.
- Bulteel, John. 1672. "A Letter written to the Publisher concerning a New Way, by an English manufacture to preserve the Hulls of Ships from the Worm, etc. better for sailing and more cheap and durable than any sheathing or graving hitherto used," *Philosophical Transactions*, Vol. VII: 6192-6194.
- Butts. I.R. 1980. Reprint. "The Merchant's and Mechanic's Assistant," in *The Coppering*

of 19th Century American Merchant Sailing Ships,” by E.A.R. Ronnberg.
Nautical Research Journal 26(3): 145. Originally published by I.R. Butts and
Company, Boston, 1856.

Chapelle, Howard I. 1935. *The History of American Sailing Ships*. New York: W.W.
Norton Company.

Childers, Spencer, ed. 1970. *A Mariner of England: An Account of the Career of William
Richardson from Cabin Boy in the Merchant Service to Warrant Officer in the
Royal Navy [1780 to 1819] as Told by Himself*. London: Conway Maritime
Press.

Church, A.C. 1938. *Whale Ships and Whaling*. New York: W. W. Norton.

Collins, William. 1818. “Patent Specification for an Improvement in Composition and
Preservation for the Manufacturing Thereof into Sheets or Plates.” *The Repertory
of Arts, Manufactures, and Agriculture* 32, second series. London: J. Wyatt.

Crothers, William. 1997. *The American Built Clipper Ship: 1850-1856. Characteristics,
Construction, Details*. Camden: International Marine.

- Flick, Carlos. 1973. "Muntz Metal and Ship's Bottoms." *The Transactions of the Birmingham and Warwickshire Archaeological Society* 87: 70-88.
- Gray, John. 1830. "Patent Specification for a New and Improved Method of Preparing and Putting on Copper Sheathing for Shipping." *Franklin Journal and American Mechanics' Magazine* 10: 172-173.
- Hale, Thomas. 1695. Reprint. *Mill'd Lead*. London: University of London. Original edition, London: Advertisement (No Publisher), November 20, 1695.
- Hall, Henry. 1884. *Report on the Ship-Building Industry of the United States*. Washington, D.C.: Department of the Interior, Census Office. Tenth Census, Volume 8.
- Hamilton, D. L. 2004, 22 February. *Online Conservation Research Lab Manual*. <http://nautarch.tamu.edu/napcrl.htm> (2004, 22 February).
- Harris, J.R. 1966. "Copper and Shipping in the Eighteenth Century." *Economic History Review* 19: 550-568.
- Hawkins, Sir Richard. 1933. *The Observations of Sir Richard Hawkins*. In "The

Observations of Sir Richard Hawkins,” edited by J. A. Williamson, London: The Argonaut Press. Original edition, London: no publisher listed, 1622.

Hocker, Fred. 1989. “Lead Hull Sheathing in Antiquity,” in *Proceedings of TROPIS 3: Third International Symposium on Ship Construction in Antiquity*, edited by H. Tzalas, 197-206. Athens: Hellenic Institute for the Preservation of Nautical Tradition.

Honson, C. C. Sylvester, and J. Moorehouse. 1806. “Patent Specification for a Method of Sheathing Ships ...Not Heretofore Used for Those Purposes.” *The Repertory of Arts, Manufactures, and Agriculture* 9, second series. London: J. Wyatt.

Knight, R.J.B. 1976. "Early Attempts at Lead and Copper Sheathing." *Mariner's Mirror* 66: 292-294.

Laidlaw, F.B. 1952. “The History of the Prevention of Fouling,” in *Marine Fouling and Its Prevention*, edited by A.C. Redfield and B.H. Ketchum. Annapolis: Naval Institute Press.

MacGregor, David R. 1982. *Schooners in Four Centuries*. Annapolis: Naval Institute Press.

MacGregor, David R. 1997. *The Schooner*. Annapolis: Naval Institute Press.

Muntz, George. 1833. "Patent Specification for Invention of an Improved Manufacture of Metal Plates, for Sheathing the Bottoms of Ships." *Franklin Journal and American Mechanics' Magazine* 16:195-6.

Muntz, George. 1834 "Patent Specification for Improved Manufacture of Bolts, and other, the Like, Ship's Fastenings." *Franklin Journal and American Mechanics' Magazine* 17: 44-5.

No author. 1835. "Patent Bronze Sheathing." *Franklin Journal and American Mechanics Magazine* 18: 206-8.

Pattison, G.S. 1829. "Notice of a Patent for Iron Sheathing for Ships." *Franklin Journal and American Mechanics' Magazine* 8: 94-96.

Petty, William. 1691. *The New Invention of Mill'd Lead for Ship Sheathing*. London: Published report for the Admiralty.

Revere, John. 1831. "Revere's New Alloy for the Sheathing of Ships." *Franklin Journal and American Mechanics' Magazine* 12: 29.

Ronnberg, E.A.R. 1980. "The Coppering of 19th Century American Merchant Sailing Ships," *Nautical Research Journal* 26(3): 125-148.

Royal Society of London. 1665/6. "An Extract of a Letter, Written from Holland, about Preserving of Ships from Being Worm-eaten." *Philosophical Transactions I*: 190-191

Staniforth, Mark. 1985. "The Introduction and Use of Copper Sheathing - A History." *The Bulletin of the Australian Institute for Maritime Archaeology* 9: 21-48.

Underhill, Harold A. 1952. *Deep-Water Sail*. Glasgow: Brown, Son and Ferguson.

Uzielli, Mathew. 1831. "Patent Specification for the Preparation of Certain Metallic Substances, and the Application Thereof to the Sheathing of Ships." *Franklin Journal and American Mechanics' Magazine* 12: 137-139.

Wetterstadt, Charles. 1832. "Patent Specification for a Composition or Combination of Materials for Sheathing." *Franklin Journal and American Mechanics' Magazine* 13: 411-412.

Whiteman, Maxwell. 1971. *Copper for America*. New Jersey: Rutgers University Press.

Winfield, Rif. 1997. *The 50-Gun Ship*. London: Caxton Publishing Group.

SUPPLEMENTAL SOURCES CITED

Basch, L. 1979. "The Metal Sheathing of Roman Warships." *Mariner's Mirror* 65: 129-35.

Blackman, D.J. 1972. "Further Early Evidence of Hull Sheathing." *International Journal of Nautical Archaeology* 1: 117-119.

Blake, W. and J. Green. 1986. "A Mid-XVI Century Portuguese Wreck in the Seychelles." *International Journal of Nautical Archaeology* 15: 1-23.

Bompas, G. G. 1835. "Remarks on the Protection Of Copper Sheathing upon Ships' Bottoms." *Franklin Journal and American Mechanics' Magazine* 19: 283-286.

Booth, Abraham. 1833. "Observations on a New Metallic Sheathing for Ships' Bottoms." *Franklin Journal and American Mechanics' Magazine* 15: 266-269.

Brooking, Admiral. 1695. "An Account of Lead Sheathing, Formerly Used for the

Protection of Ships' Bottoms," extracted from a work published in 1695, titled *An Account of Certain Plans and Suggestions for the Improvement of the Rudder, Stern-Post, and Steering Wheel, now used in the ships of His Majesty's Navy*.
Plymouth: Rowe 9, Whimble Street.

Casson, L. 1978. "More Evidence for Lead Sheathing on Roman Craft." *Mariner's Mirror* 64: 139-141.

Cock, Randolph. 2001. "The Finest Invention in the World: The Royal Navy's Early Trials of Copper Sheathing, 1708-1770." *Mariner's Mirror* 87: 446-459.

Crisman, Kevin J. 1999. "Angra B: The Lead-sheathed Wreck at Porto Nova." *Revista Portuguesa De Arqueologia*, Volume 2, numero 1.

Finchham, J. 1851. *A History of Naval Architecture*. London: Scolar Press, 92-101.

Frost, H. 1978. "Warships and Lead Sheathing: A Reply." *Mariner's Mirror* 64: 142-144.

Gardiner, Robert, ed. 1993. *Conway's History of the Ship: Sail's Last Century: The Merchant Sailing Ship 1830-1930*. London: Conway Maritime Press.

Glasgow, Jr. T. 1967. "Sixteenth-century English Seamen Meet a New Enemy – The Shipworm." *American Neptune* 27: 177-185.

Gorham, L. Dillon and Vaughn M. Bryant. 2001. "Pollen, phytoliths, and other microscopic plant remains in underwater archaeology." *International Journal of Nautical Archaeology* 30.2: 282-298.

Greenhill, Basil. 1968. *Merchant Schooners, Volumes 1 and 2*. New York: Augustus M. Kelly Publishers.

Greenhill, Basil. 1980. *Schooners*. Annapolis: Naval Institute Press.

Haines, Charles. 1982. Ship Preservation in the Old Navy. *American Neptune* 42: 276-294.

Haring, C. H. 1964. *Trade and Navigation Between Spain and the Indies in the Time of the Hapsburgs*. Gloucester, Massachusetts: Peter Smith Company.

Harland, J.H. 1973. "Piet Heyn and the Early Use of Copper Sheathing." *Mariner's Mirror* 62: 1-2.

Knight, R.J.B. 1973. "The Introduction of Copper Sheathing into the Royal Navy,

1779-1786.” *Mariner's Mirror* 59: 299-309.

Lever, Darcy. 1998. Reprint. *The Young Sea Officer's Sheet Anchor or the Key to the Practical Leading of Rigging and to Practical Seamanship*. New York: Dover Publications. Original edition: Published by John Richardson, London, 1819.

Lunn, Iver. 1974. *Antifouling: A Brief Introduction to the Origins and Development of the Marine Antifouling Industry*. Thame, England: BCA Publications/Iver Lunn & Company, Ltd.

MacGregor, David R. 1984. *Merchant Sailing Ships: 1815-1850*. Annapolis: Naval Institute Press.

MacGregor, David R. 1984. *Merchant Sailing Ships: 1850-1875*. Annapolis: Naval Institute Press.

Morris, Paul C. 1973. *American Sailing Coasters of the North Atlantic*. Chardon, Ohio: Bloch and Osborn Publishing Company.

Oog, George. 1817. On The Cure and Prevention of Dry Rot in Ships of War. *Philosophical Transactions* 31: 26-40.

- Prideaux, M. 1842. "Some Inquiries into the Causes of Increased Destructability of Modern Copper Sheathing." *Franklin Journal and American Mechanics' Magazine* 33: 104-108.
- Rees, G. 1971. "Copper Sheathing: An Example of Technological Diffusion in the English Merchant Fleet." *Journal of Transportation History* 1(2): 85-94.
- Smith, Edward W. Jr. 1975. *Workaday Schooners: The Edward W. Smith Photographs*. Camden: International Marine Publishing Company.
- Wilkinson, J.J. 1842. "On Wood, Lead, and Copper Sheathing." *Nautical Magazine and Naval Chronicle* 11: 400-404.
- Wood, William. 1815. "Manufacture of a Material or Materials, and the Application Thereof, to the more Effectually Making Water-tight and Sea-worthy Ships." *Philosophical Transactions* 29: 151-157.
- Zimmerman, Walter J., Jr. 1978. "A Method for Coppering Models." *Nautical Research Journal* 24:2.

APPENDIX A

*NR-1 Dive Logs*Toby N. Jones's *NR-1 Dive Log*

Time Activity

24 July 2002

0530 Departed Biloxi, Mississippi, on the chartered fishing vessel *Outrageous*.

1100 Rendezvoused with the SSV *Carolyn Chouest* and the USN *NR-1*.

1120 Transferred by RHIB to *NR-1*. Met crew and prepared to dive. Installed the Seabotix ROV and dived. The Seabotix ROV popped out of the Tether Management System. *NR-1* surfaced and the RHIB crew removed the ROV from the TMS.

1200 Dived again and vessel rigged for deep submergence. Reached the bottom at 2900 feet. The three parallel pipelines were found and the *NR-1* traveled along the pipeline until the wreck appeared on the sidescan sonar at 1517. The wreck also appeared on the Obstacle Avoidance Sonar (OAS).

1525 A grid was laid out for obtaining plan footage of the wreck.

- 1531 Achieved visual confirmation of the wreck with a fly around of the stern.
Beginning side scan mosaic 15 foot altitude and 600 kHz resolution.
(Depth 2660 feet) Length of 67 feet according to OAS.
- 1610 Continued with side scan survey of wreck site. Excellent 600 kHz sidescan images with a North-South orientation.
- 1625 Side scan completed.
- 1630 *NR-1* positioning for video mosaicing. Received word that the *MaxRover* ROV on the surface was in need of repair. Due to its delayed launch, we will proceed with sediment sampling after the mosaic is complete.
- 1635 Decided to place sediment sampling as first priority. Followed by video mosaicing and expanding box survey. Upon completion, the sub will moved approximately 200 feet down the pipeline to investigate an object that appeared on side scan.
- 1636 The *NR-1* bottomed out and moved forward at 0.33 knots to gain wreck visually.
- 1649 Gained wreck visually. Excellent footage of wreck appearing from the darkness.
Filling external hydraulics in preparation to retrieve sediment samples.

- 1725 Excellent footage of a shark.
- 1740 The work module containing the sediment tubes is lowered and the manipulator arm is readied. The operators can't get the manipulator jaws to open. The manipulator is stowed.
- 1815 Preparing to move the *NR-1* into position for plan view video mosaicing.
- 1830 Images of port quarter bow. Excellent close-up of keelson, bolts, artifacts. Copper nails in rows, not plan footage. *NR-1* changing position and moving from port quarter (NW) to starboard quarter (NE), driving along the bottom and coming to the wreck oriented SW (bow) and NE (stern).
- 1900 Now moving instead to SE corner, coming in with bow facing NW and stern facing SE.
- 1925 Continue maneuvering.
- 1935 Bottoming and driving to the SE corner.
- 1947 129 feet from wreck, closing at 2/10 of a knot.

- 2000 View of deep sea coral and stern sheathing nailing pattern details.
- 2010 Close up of starboard stern copper sheathing details. Looking for makers mark.
- 2016 Close up of shiny white object lying on surface high in the stern. Likely ceramic, possibly glass or pewter.
- 2025 Close up of artifact high in the starboard stern.
- 2035 Video capture of small pile of copper alloy spikes.
- 2050 Leaving bottom to commence photo mosaic.
- 2110 Commencing video mosaic. Run #1. Far starboard, beginning run from the south.
- 2120 Run #2. Practice run, washed out footage.
- 2130 Run #3. Practice run, washed out footage.
- 2140 Run #4. Recorded, but poor visibility.

- 2150 Run #5. Recorded, but poor visibility. Recorded at 20 foot altitude, longitudinal passes. End first plan mosaic.
- 2200 Object sited north of wreck on side scan sonar. Begin expanding box grid search pattern at 20 foot altitude, SSS and video, 90° corners.
- 2215 Test pass in high frequency. Mica wreck shows up in nadir, still partially visible. Trying lower frequency (150 kHz) to change resolution.
- 2240 Continuing expanding box survey, (two hits on SSS).
- 2245 One hit is metal. Will investigate later. Proceeding to investigate hit number 2.

25 July 2002

- 0155 Obtained visual on hit #2. Appears to be 4 stones/anchor rocks bundled together with rope. There is considerable growth on the rocks obscuring their surface. Closer inspection reveals that the rocks appear to be wrapped in fish net. Could be trash that was bundled up and ballasted. Modern looking rope. Net has wide spaces. Could be trash from the laying of the pipeline. Reasonable explanation.

- 0200 Preparing to make second video mosaic. Variable current velocity and direction. The *NR-1* is flying at 8-10 feet altitude. Excellent visibility. Mosaicing commences. Get 2 hours of sleep in rack. Mosaicing finished and NR-1 is maneuvered and bottom in the NE quadrant. Begins driving toward wreck.
- 0545 Parked over NE corner of wreck.
- 0610 Shot of rigging element, possible dead eye or chain plate.
- 0620 Crawled down to view ports. *NR-1* is parked over the NE corner of the wreck. Tried photographing the wreck through view ports. Looked at blocks/tire tracks aft of stern. Poor visibility and lighting.
- 0800 Decide to surface and discuss new priorities based on findings.
- 0913 Broke the surface after 21 hours and 13 minutes underwater. Proceeded to vicinity of SSV *Carolyn Chouest*.
- 0930 Transferred by RHIB to SSV *Carolyn Chouest*. Briefing with the surface crew. Decide to continue with the planned artifact (scientific sample) collection and sediment sample collection. *MaxRover* is still inoperable. Surface crew preparing to modify artifact lift or make a new one that can be lowered by the submarine.

The archaeologists are evaluating the feasibility of examining other wreck sites in the region. Decision made to keep Toby on *NR-1* for planned artifact recovery in concert with the *MaxRover*.

1030 Transfer from SSV *Carolyn Chouest* to *NR-1* via RHIB. The manipulator is being repaired.

1200 Preparing to dive, manipulator arm is working.

1210 Commencing second dive to Mica wreck site.

1215 *NR-1* rigged for deep submergence.

1420 *NR-1* arrives on site, landing in a previous tire track.

1430 SSV *Carolyn Chouest* launches *MaxRover*.

1451 SSV *Carolyn Chouest* orders *NR-1* to surface and maintain distance. *MaxRover* down.

1454 *NR-1* departs area and surfaces at 1-3 feet per second. The bow angle averages 11° and reaches 15°. Quite a ride.

1520 *NR-1* stops at periscope depth and scans horizon for SSV *Carolyn Chouest*.

Notes her position and completes surfacing. Transfer by RHIB to SSV *Carolyn Chouest*.

End Toby Jones's *NR-1* dive log.

Dr. Rik Anuskiewicz's *NR-1* Dive Log

Time Activity

26 July 2002

1745 Departed SSV *Carolyn Chouest* and arrived at *NR-1* at 1750. *NR-1* remained on surface until 1820.

1820 *NR-1* began deep dive (Rigged for Deep Submergence) after blowing ballast and sinking to 30 feet and then 50 feet. The vessel has two men up front, the helmsman (vessel pilot)(port seat) and the deck officer (starboard seat).

1845 Briefed the captain (OIC Dennis McKelvey) on the archaeology mission and also on the MMS and its mission and my roll with the MMS. During my discussion with the captain, we discussed the basic mission and I asked if we could pick up a measuring rod left on the wreck site from the March (February??) 2001 ROV investigation and move it the starboard bow quadrant of the wreck. He said he would try, but the pipeline was leaning against the 8 inch ExxonMobil pipeline and that he would have to be very careful.

1937 We began moving in on the wreck by doing a flyby over the pipeline to locate the measuring rod.

- 1947 Found the pipeline. The main center camera system is having “iris” (Light problems). Met the helmsman (Richard) and the Deck Officer (Larry- Chief Engineer). Visibility on the bottom is poor. Traveling up pipeline from 2736 feet towards the wreck.
- 2051 Found the wreck. Maneuvering to get in position to retrieve measuring stick. The bottom current is strong, decided to come in from another angle.
- 2300 Shift change on *NR-1*. Helmsman and Deck Officer switch out.
- 2345 Located measuring bar approximately 100 feet from southwest quadrant.

27 July 2002

- 0130 Measuring bar picked up by *NR-1* manipulator arm. *NR-1* proceeded to back off in order to drop the meter stick in the center of the wreck near keelson spikes.
- 0225 Maneuvering to drop measuring bar near the mast step. Ship Operation: The helmsman steers the submarine but is directed by the deck officer.

- 0342 Cannot land the submarine in the starboard bow quadrant because of the angle of the current. Therefore, we are positioning in the port stern quadrant to begin nudging a few artifacts. Deployed articulated arm.
- 0418 The Captain asked me to crawl into the forward view port area as he tried to fan off and nudge a few artifacts. They appeared to be brittle. I returned at 0524 and observed that using the manipulator arm is very time consuming and labor intensive when used to nudge artifacts.
- 0539 Activated forward thrusters near the portside stern to see how long it will take to clear up.
- 0604 Thrust continuing and cleaning out around pipeline. After three thrusts, the interior planking was exposed, with frames and ceiling planking possibly visible.
- 0628 Positioning submarine to work thrusters in toward the keelson pins. Continued dust off up the pipeline, clearing a large area away, uncovering the round object. After several dustings, the round object seemed to partly disintegrate. A camera scan of the keelson pins showed a slight tilt to port, of approximately 10-15 degrees, indicating that the keelson had shifted to the west.
- 1000 *NR-1* surfaced, with the dive ending at 1000 on 27 July 2002.
- End Dr. Rik Anuskiewicz's *NR-1* dive log.

Dr. Kevin J. Crisman's *NR-1* Dive Log

Time Activity

27 July 2002

1120 Commence Dive on *NR-1*.

1345 On site of Mica Wreck. Commencing Video Mosaic Flyover. Stern to bow. Height above bottom: 15 feet. Good Visibility-approximately 20 feet. Near perpendicular coverage.

1410 Complete mosaic pass. Maneuvered into port stern quarter quadrant for dust off amidships area abaft of pipeline. Slight current from starboard and forward.

1417 *NR-1* bottomed, facing Easterly, Depth 2657 FSW.

1430 Dust off of degraded planking on port side of wreck abaft of pipeline. The recovery of the reference bar from February 2001 ROV survey also to be attempted with *NR-1* manipulator arm. *NR-1* rolling forward.

1505 Reference bar picked up. To be retained until needed for artifact reference or when dust off completed.

1510 Dusted off starboard side, just forward of the pipeline. Fast dispersion of silt. Inspection: two unidentified fragments.

- 1515 Second squirt with duster. Lumpy-Possibly stone ballast?
- 1517 Another slightly longer blast. Small stone ballast? Forward of pipeline, starboard side.
- 1520 Fourth dust off.
- 1529 Object with straight line under pipeline.
- 1536 Silt clears, visual inspection along both sides of pipeline. Shallow U-shaped object forward of pipeline. Stick or Dunnage. Plank with nails or tacks directly adjacent to starboard side of keelson or keelson bolts. Lumps that looked like ballast are not so evident- probably just silt and not ballast. A copper strip tacked to a plank (Figure A-1).

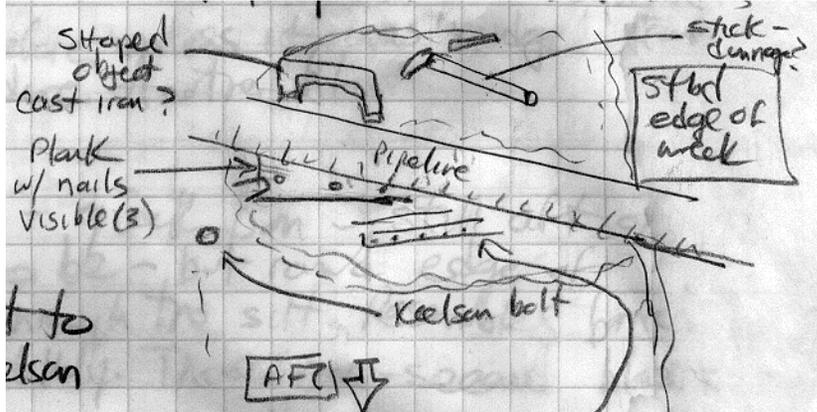


Figure A-1.

1540 Two “squirts” sustained to clear area.

1555 Inspected area...not much more visible. Stick or dunnage has crooked end.

Decide to back up *NR-1* and reposition slightly so that thruster is directed upon hull centerline to clean down to level of keelson or floor tops.

1605 Back up...waiting for dust to settle...pull ahead.

1608 Pulled forward into center of wreck and give experimental blast to see if we are over keelson.

1615 Run visual survey as dust clears. We are further aft and to port than required to dust off keelson. Run slow pan aft to forward along inside of starboard edge aft of pipeline. See clear spike, bottle base, short, rod-like object (chainplate?).

- 1620 Repositioned. Pan shows nice deadeye strap with base oriented to starboard.
Don't believe I've seen it before, unless it was 'nudged' from port on Rik's dive.
Another blast.
- 1622 Dust settles. Quick pan. Still aft of where we want to be, but round edge of something poking through the silt. Resembles barrel edge, seems unlikely. Three one-second blasts in same area.
- 1625 Not much visible. Three second blast when dust clears, see curved edge about the same as last time. Pan area. Look closely at dead eye strap last seen at 1620.
Looks like surface has eroded from dusting. This iron is fragile! And I think this is actually the port side deadeye strap we've seen earlier in this area. Back up and pull forward so thruster now centered on area just abaft of pipeline and keelson bolt- time to look for evidence of the keelson.
- 1635 Repositioned—lengthy blast with thruster. We seem to be port of hull centerline, with thrusters angled forward and starboard. Sub's position is aft of pipeline along centerline keelson bolts.
- 1642 In right spot. Inspect. Then two sustained blasts to same area. KJC suggests parking and dusting for a while in this area.

1645 XO thinks we're directing too much of thrust towards starboard. Backing up to hit centerline more directly.

1650 Dust and Look (Figure A-2).

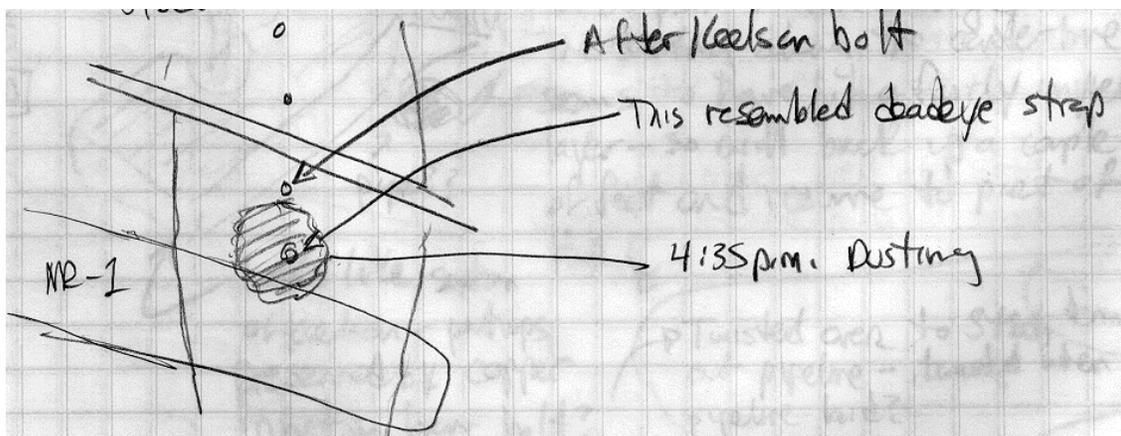


Figure A-2.

1655 Dust and Look

1657 Another dusting. Current (estimated $\frac{1}{2}$ knot) removing sediment nicely.

1700 Another blast. Small piece of sheathing has turned over and rows of tack holes visible. Small patch or something to do with pump.

1707 Blast. Inspect. Longer blasts kicking up less silt. Suggests that we are down to denser material that resists thruster.

1712 Blast. Inspect. Not much progress. Water pressure may not be enough for this job.

1730 Watch change. The dusting along the centerline seems to hit a fairly unyielding layer. So will back up a couple of feet and resume to port of hull centerline.

Twisted over to starboard. Out pipeline. Twisted when pipeline laid (Figure A-3).

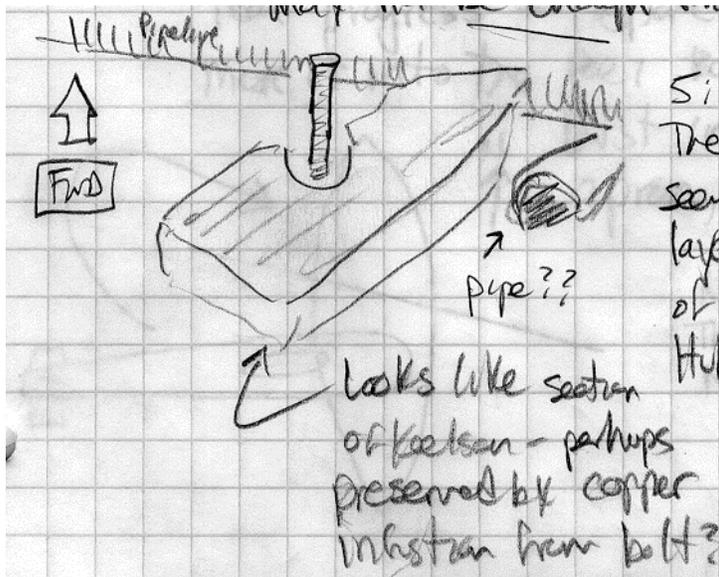


Figure A-3. Illustration depicting part of keelson section, perhaps preserved by copper infusion from bolt.

- 1745 Finished back-up. Scan port and side aft. See round object near edge port side. Get video capture. Also capture of deadeye strap on port side. See illustrations in notes. Round object 3” to 4” diameter, looks like copper sheet, deadeye strap.
- 1750 Jet area to port side of earlier work. Noted long *Teredo navalis* tube—one end white. Evidence of ship’s demise on bottom. Teredo tubes likely to be mistaken for man made items.
- 1755 Move back into wreck about two feet to jet beneath centerline and port edge of wreck.
- 1800 *NR-1* moves back into toward wreck centerline and shifts aft.
- 1805 Decided we’ve done enough jetting here. No real progress. Prepare to reposition sub and move it into port bow area. Will attempt to dust inside of cant frames and apron. Then do close-up inspection. *NR-1* moves well off site, then lands and rolls in from northwest. (Illustration in notes).
- 1915 Visual reconnaissance of stem interior from port edge of hull beneath bow and pipeline (Figure A-4).

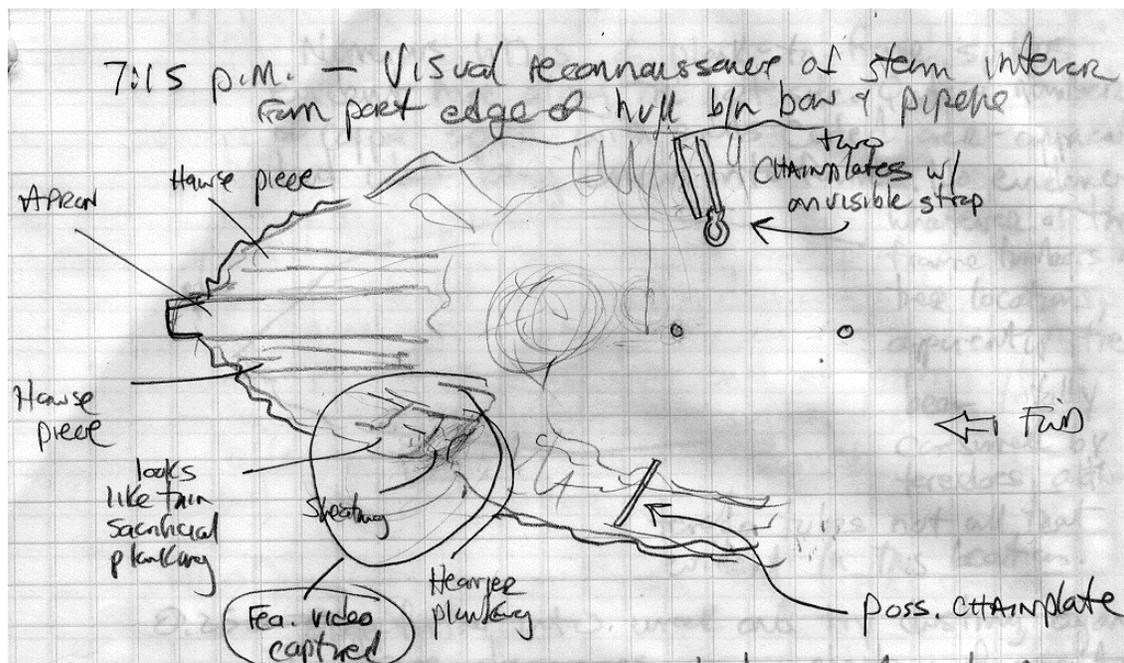


Figure A-4.

1942 Thruster directed inside bow and initial rub—great clouds of silt up in water column. Some thruster damage evident to after edge of plank/sheathing on port side. Three video captures made at this point.

1. two chain plates on starboard side
2. plank/sheathing feature before dusting
3. plank/sheathing feature after dusting

Post-dusting showed unmistakable evidence of thin wide sacrificial planking over narrower thicker outside planking.

- 2000 Another jet on bow. Double planking very evident. Thruster hitting more on the edge of the port side than the inside, so not all that effective in removing sediment over apron. Also, sub shifting from side to side in the many tire ruts in this area.
- 2012 Try *NR-1*'s starboard thruster, jetting aft along port side. Pause and review. Numerous lines of plank-to-frame spikes evident here along the port side. Quite a number of copper spikes with ends curled over—apparently while being driven into frames. No evidence whatever of the frame timbers in these locations, apparently they have been totally consumed by teredoes, although Teredo tubes not all that evident in this location.
- 2025 Edge further into wreck and try dusting again. No major discoveries—many sheathing fragments in bow (small), detached copper spikes, unidentifiable stuff.
- 2035 Try edging further into wreck, given considerable bow-up angle that requires Capt's attention.
- 2040 After another dust-off, Capt. and Officers spot wedge shaped object near port side edge, abaft of our position. Take five second video grab for our files.

- 2050 Jet to port side of sub (into area immediately aft of wreck stern. Much mud and small bits. We've moved further into wreck, so hopefully we'll avoid excessive damage to plank and sheathing edge. Nope, we damaged it some more. We're definitely done in this area.
- 2100 Evident that we've done what's to be accomplished in bow, so confer with Captain about next steps. Will lift out of bow, maneuver aft on wreck and attempt to place measuring bar flat on wreck. Will then back out to port and recover core samples from port side of wreck abaft pipeline, and from outside of wreck in same area. Subsequently, at mid watch, will attempt to remove upper end of sternpost and recover same. Captain also suggested we may be able to recover sheathing sample elsewhere with the manipulator arm.
- 2110 Captain instructs Engineer and Pilot of next set of maneuvers.
- 2230 Dropped down on wreck and deposited measuring bar in center of wreck, flat on bottom, just forward of pipeline.
- 2235 Maneuvering *NR-1* perpendicular to wreck, we'll then use thrusters to move aft and nudge sternpost assembly to detach it in an aft direction. Visibility very poor, so we will hold in the water column for a while until conditions improve.

Commence wide circle to west of wreck site to await better visibility. At 2325, still quite murky.

2340 After change of watch, come in from west side of wreck, straddle it with sub and use side thrusters to back over sternpost. Barely brush top of post. Back around for second approach.

2355 pass just over post, then dropped down with hull and applied downward pressure. Gudgeon and top of post appeared to separate and fall to bottom. Back up and see gudgeon free on bottom (Figure A-5).

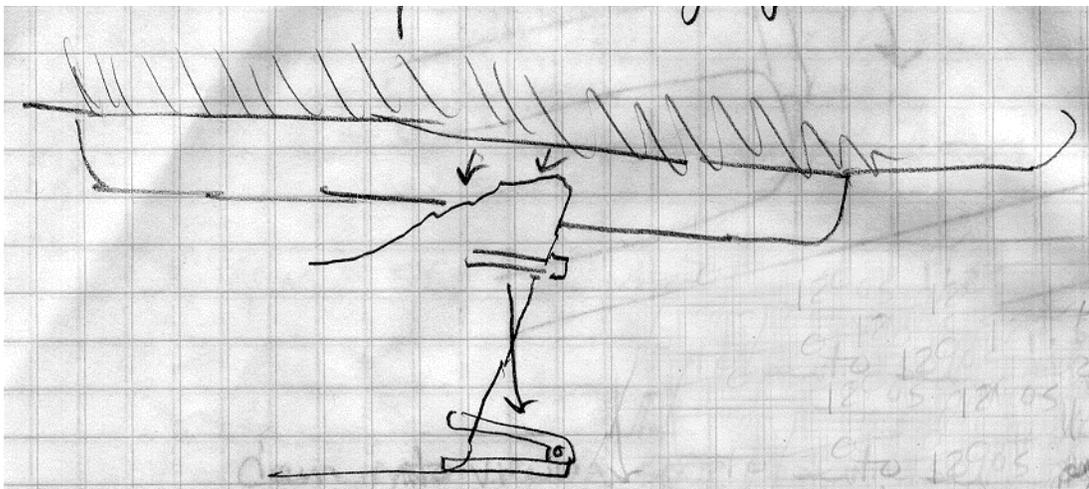


Figure A-5.

28 July 2002

0005 Sub then bottoms out alongside port side of wreck. Will allow sediment to settle and then will reach in with manipulator arm to retrieve gudgeon.

0030 Commence inspection of detached upper sternpost. Post broken just above lower gudgeon. Frame grabs made of upper, lower gudgeons, skeg (Figure A-6).

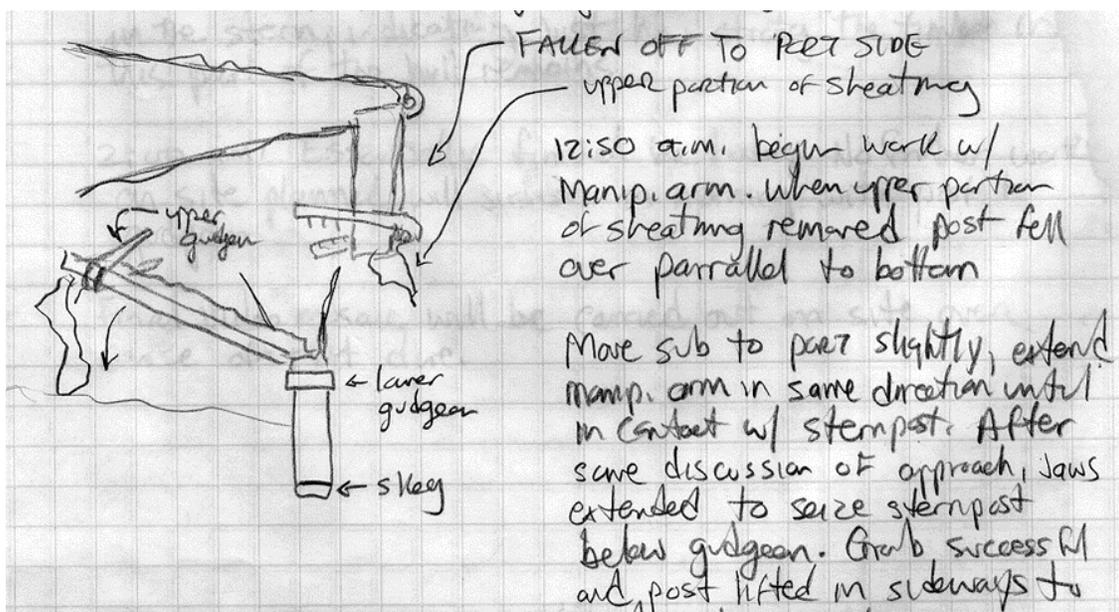


Figure A-6.

- 0050 Begin work with manipulator arm. When upper portion of sheathing removed, post fell over parallel to bottom. Move sub to port slightly, extend manipulator arm in same direction until in contact with sternpost. After some discussion of approach, jaws extended to seize sternpost below gudgeon. Grab successful and post lifted in sideways to underside of sub.
- 0125 Post and gudgeon suspended under submarine. Lengthy pause while various members of crew and KJC climb down into viewing space to see piece firsthand. Port side of stern sheathing and planking has peeled outward slightly, but otherwise minimal damage to structure is evident. Curiously, after a 150' nuclear submarine has leaned heavily upon the top of the sternpost and broken half of it off, the keel is still up off the bottom in the stern, indicating just how strong the timber in this part of the hull remains (Figure A-7).

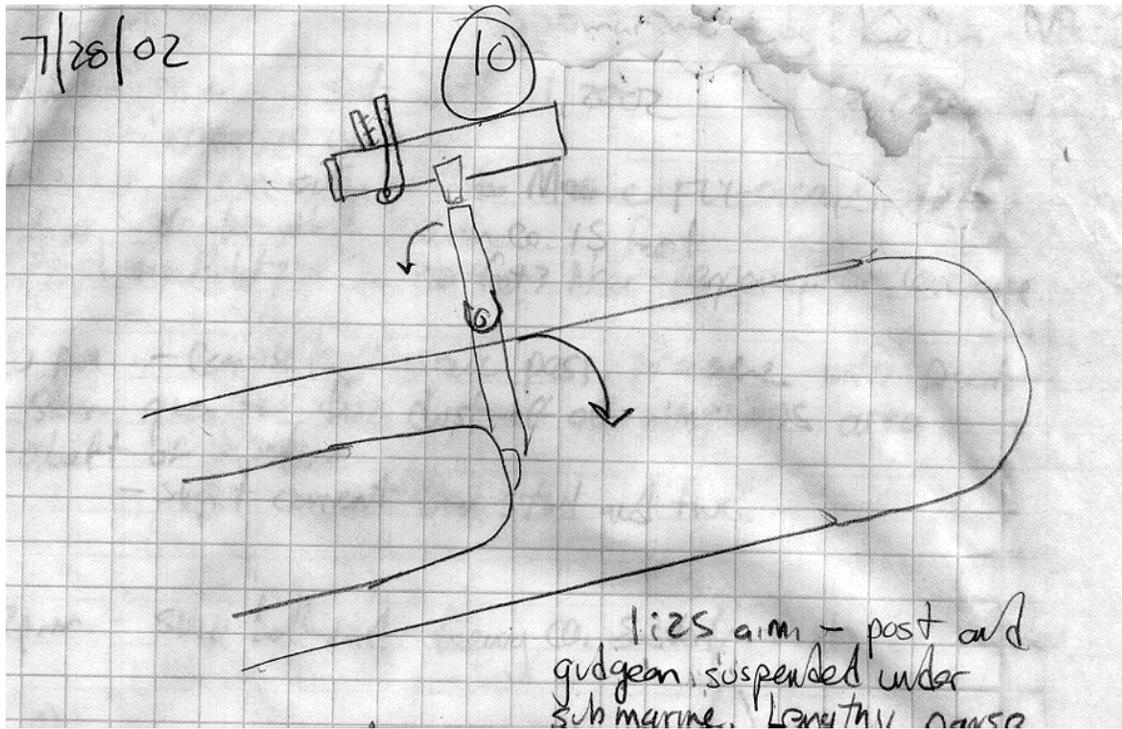


Figure A-7.

0200 Essentially finished for today. No further work on site planned, will surface in morning with post and gudgeon. Final video mosaic will be carried out on site over course of next dive.

End Dr. Kevin J. Crisman's *NR-1* dive log.

APPENDIX B

MICA SHIPWRECK ARTIFACT CATALOG

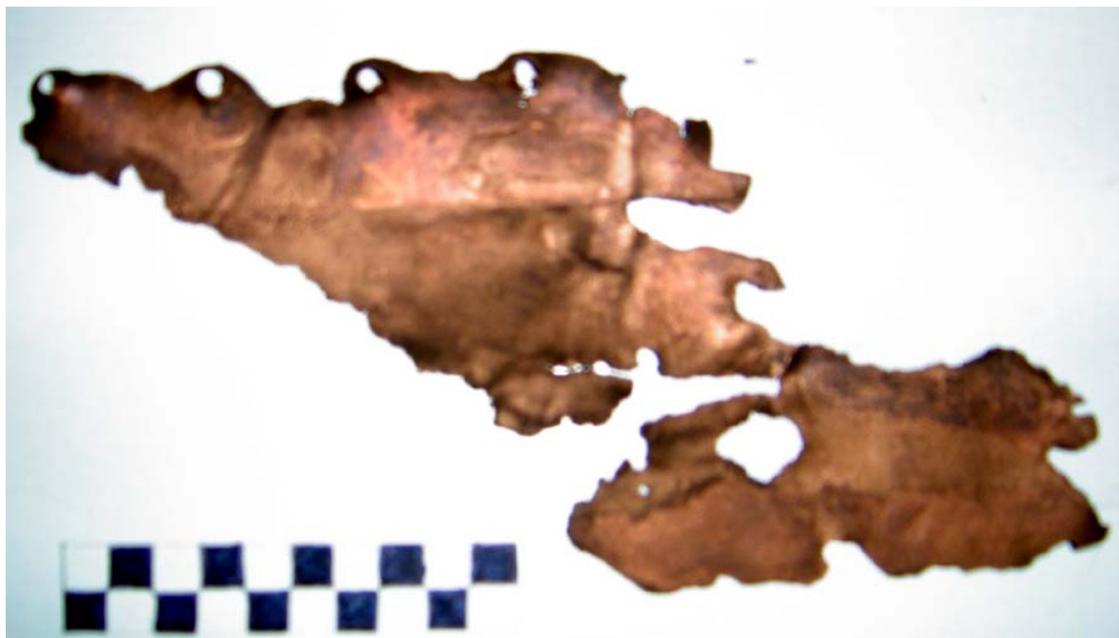


ARTIFACT 1

Description: Fragment of copper hull sheathing

Dimensions: 35.0 centimeters x 18.3 centimeters

Features: Appears to be the side edge of a sheet, as two corners are visible. 17 fastener holes visible. Sheathing overlap line is perceptible along the upper edge. Largest fragment of hull sheathing retrieved.



ARTIFACT 2

Description: Fragment of copper hull sheathing

Dimensions: 26.5 centimeters x 12.0 centimeters

Features: 4 fastener holes visible, no edges evident



ARTIFACT 3

Description: Fragment of copper hull sheathing

Dimensions: 14.5 centimeters x 10.8 centimeters

Features: One edge visible, possibly a corner fragment. 6 fastener holes visible.



ARTIFACT 4

Description: Fragment of copper hull sheathing

Dimensions: 8.5 centimeters x 8.2 centimeters

Features: 2 fastener holes visible, 1 fastener, no edges.



ARTIFACT 5

Description: Fragment of copper hull sheathing

Dimensions: 14.5 centimeters x 7.5 centimeters

Features: 4 nail holes, no edges.



ARTIFACT 6

Description: Copper alloy sheathing fasteners

Dimensions: 14.5 centimeters x 10.8 centimeters

2.8-3.8 centimeters in length

0.4 centimeter average shank diameter

Features: Flat head, tapered shank.



ARTIFACT 7

Description: Lead Hawse Pipe

Dimensions: 41.0 centimeters x 7.0 centimeters x 2.0 centimeters

Features: Casting seams, cut marks and internal wear are evident.

APPENDIX C

METALLIC SHEATHING STUDY RESULTS

The following appendix provides information on the elemental composition of select metallic ship sheathing and fastener samples tested by or submitted to the author. The tested materials are divided into copper and copper alloy sections, with a third section containing various lead items. The final page of the appendix notes the source of each metallic sample/information set.

COPPER SHEATHING

Ship/Wreck, Dates ⁹¹	Composition	Trace Elements
<i>De Braak</i> Sheathing 1798	98.5 % Cu	As ⁹²
<i>De Braak</i> Fasteners 1798	88.0 % Cu, 8.6 % Sn, 1.0 % Zn	As, Pb
Mica Sheathing	99.5 % Cu	As
Mica Fasteners	84.7 % Cu, 5.3% Sn, 7.8 % Zn	As, Pb, Bi
<i>Cleopatra's Barge</i> 1816/1824	98.0 % Cu, 2.0 % Pb	
USS <i>Alabama</i> 1819/1922	100.0 % Cu	
<i>Spring of Whitby</i> 1824	93.1 % Cu	

⁹¹ The first date reflects the construction or launch date, while the second date denotes the time of loss. If only one date is listed, it is the date of loss. If no dates are listed, than none are known.

⁹² As or Arsenic is a naturally occurring trace element commonly found in copper ore.

Steamboat <i>Washington</i> 1825/1831	100.0 % Cu
<i>Niantic</i> 1835/1851	100.0 % Cu
<i>General Harrison</i> 1840/1851	100.0% Cu

COPPER ALLOY SHEATHING

Ship/Wreck, Dates	Composition	Trace Elements
De Rosa Samples	62.7 % Cu, 37.2 % Zn	Pb
<i>Robert</i> ⁹³ 1800	62.5 % Cu	
<i>King Philip</i> 1856/1878	61.2 % Cu, 37.9 % Zn	Pb, Sn
<i>Mary Celeste</i> 1864/1886	Muntz ⁹⁴	
<i>Thomas F. Bayard</i> 1880/2002	Muntz	

LEAD SHEATHING/ARTIFACTS

<i>Pilar</i> 1619	99.0 % Pb	
Mica Hawse Pipe	100.0 % Pb	Cu, Bi
Modern lead	100.0 % Pb	Sn

⁹³ The date of loss for the *Robert* is suspect, because Muntz metal was not invented until 1832.

⁹⁴ Muntz metal was typically a mixture 60 % Cu and 40 % Zn.

METALLIC SAMPLE	SOURCE	DATA TYPE
<i>De Braak</i> Sheathing	Charles Fithian	Sample
<i>De Braak</i> Fasteners	Charles Fithian	Sample
Mica Sheathing	Toby Jones	Sample
Mica Fasteners	Toby Jones	Sample
<i>Cleopatra's Barge</i>	Paul Johnston	Information
USS <i>Alabama</i>	Kevin Crisman	Sample
<i>Spring of Whitby</i>	James Sinclair	Sample
Steamboat <i>Washington</i>	Peter Johnson	Information
<i>Niantic</i>	James Delgado	Information
<i>General Harrison</i>	James Delgado	Information
De Rosa Samples	Horatio De Rosa	Information/ Sample
<i>Robert</i>	James Sinclair	Sample
<i>King Philip</i>	James Delgado	Information
<i>Mary Celeste</i>	James Delgado	Information
<i>Thomas F. Bayard</i>	James Delgado	Information
<i>Pilar</i>	Carol Tedesco	Sample
Mica Hawse Pipe	Toby Jones	Sample
Modern lead	Toby Jones	Sample

VITA

Toby Nephi Jones received a B.A. in history from Oregon State University in 2001. In addition to participating in the Mica shipwreck investigation, he has worked on the Red River Wreck project in Oklahoma and the Episkopi Bay Survey in the Republic of Cyprus. His permanent address is 5125 NW Crescent Valley Drive, Corvallis, Oregon 97330-9721. His email address is tobynjones@yahoo.com.