EVERYTHING IS BALLAST: AN EXAMINATION OF BALLAST RELATED PRACTICES
AND BALLAST STONES FROM THE EMANUEL POINT SHIPWRECKS

by

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ABSTRACT

EVERYTHING IS BALLAST: AN EXAMINATION OF BALLAST RELATED PRACTICES AND BALLAST STONES FROM THE EMANUEL POINT SHIPWRECKS

Matthew Julian Gifford

Ballast has not often been the focus of research; where it has, the studies have been approached with various assumptions in mind. For example, specific features, such as stratigraphy, are looked for in order to define the relationship between a shipwreck and associated ballast. What all of these studies lack is a thorough explanation as to why any features would be present and how they could appear. The majority of this thesis is focused on outlining the basics and potential archaeological effects of practices which could have affected the use of stone ballast in both maritime and terrestrial contexts and led to the creation of features within the ballast in a ship’s hold. Two shipwrecks in Pensacola Bay, Florida, Emanuel Point I and II (EPI and EPII), and the results from previous ballast studies, provide a limited case on which to test the archaeological effects of the many practices. The conclusions of this thesis regarding the high level of uncertainty when studying ballast are very similar to those of previous studies; however, the basic framework provided by the descriptions of practices can be used to better explain features which have been or may be encountered on shipwrecks.
CHAPTER I

INTRODUCTION

The purpose of this thesis is to answer the question: What can be learned by studying stone ballast? To begin addressing this question, this chapter first explains what the term ‘ballast’ refers to and how this relates to the rest of the ship. Next, a discussion of published ballast studies outlines the approaches researchers have taken to identify, source, and explain the features of ballast stones and ballast piles on various sites. This is followed by a discussion of how this thesis will expand on the investigations of previous researchers, including a brief history of the shipwrecks used to examine the potential features of a ballast pile.

What is Ballast?

As long as there have been boats and ships, there has been a need to keep them upright and stable. This is accomplished by placing heavy objects in the bottom of the vessel. The term “ballast” refers to extra material placed in the lowest portions of a vessel in addition to any cargo, ordinance, and other supplies. The extra material lowers the vessel’s center of gravity and makes it stable during voyages in open water (McGrail 1989:357; Steffy 1994:8-10). Ballast generally consists of various sizes of unprocessed stone placed under, around, or on other items in the hold. The amount and weight of other items, including cargo, ordinance, and supplies, influences the amount of ballast that is loaded onto the ship. A ship filled with dense cargo needs less ballast than a ship with a light or small cargo.

In a small boat, such as a canoe, the people riding inside can act as ballast when they move themselves around and stay low in order to keep the canoe from capsizing; additional material is not always needed. Slightly larger boats and small sailing ships carry ballast at all times in the form of unprocessed stones of various sizes and/or cargo, both of which added
stability and could be easily moved as conditions changed (Agius 2008:123; McGrail 1989:357). Larger ships, including large Spanish ships of the sixteenth century, require more weight to keep them stable and use a combination of large and small stones which cannot be removed from the vessel without destabilizing it (Lamb 1988:6). Other ballast materials, including dirt, coral, metal, and water have also been used to varying degrees over the centuries; these materials may be found mixed among stone ballast or used on their own depending on the time period in which the particular vessel was active.

Aboard all vessels, ballast influences four main characteristics related to how a floating vessel sits in the water and reacts to changing conditions; these are the stability, freeboard, draft, and trim. Stability is related to the amount of weight placed onboard. The weight affects a vessel’s ability to stay upright and react as it should when returning to an upright position, i.e. not uprighting too slowly or quickly (McGrail 1989:354). Freeboard and draft are also influenced by the amount of weight. The freeboard is the distance between the uppermost deck and the water and decreases with the addition of ballast. Without adequate freeboard, water may wash onto the deck and cause the ship to sink. The draft is the distance from the waterline to the bottom of the keel, and is inversely related to the freeboard; as one increases, the other decreases. If a vessel has too much draft, as a result of carrying too much ballast, it may not be able to navigate over sandbars or up rivers. Adding or removing ballast to adjust the previous three attributes can also affect the trim of the vessel. The trim refers to the distribution of weight and the need to balance the ship so it sits in the water at the correct angle, i.e. not tilted any more than necessary in any direction (McEwen and Lewis 1953:571).

These four attributes are adjusted in relation to each other as well as to a theoretical point in the center of the ship called the metacenter (McEwen and Lewis 1953:340; McGrail 1989:357).
The metacenter is the point around which the buoyancy of the vessel must center in order to safely operate. If the center of buoyancy is above the metacenter, such as when there is not enough ballast, the ship will be in danger of capsizing. If the center of buoyancy is too low, as a result of too much weight being onboard, excess strain may be placed on the ship and its crew when the ship uprights itself too quickly. Too little weight produces the opposite effect; the ship may not upright quickly enough which could be disastrous during inclement weather. The lateral distribution of weight must also be centered around the metacenter. If too much weight is on either side or either end, the ship will tilt in the direction of the weight.

Over the lifetime of any vessel which must carry a large amount of ballast to remain stable, adjustments to the amount and distribution of weight will be made whenever the ship takes on or drops off any cargo, supplies, or ordnance. Certain necessary procedures, such as careening and stowage, also involve the removal and/or movement of weight. These adjustments and procedures, which can result in the addition, removal, or movement of a portion of the ballast, may leave visible features within the ballast pile. In a few cases, maritime archaeologists have attempted to identify and use these features in their research. As the ballast studies outlined in the next section demonstrate, archaeologists who examine ballast often provide little or no information to explain what features they expect to find and why those features may be present. Some researchers briefly explain particular features of the ballast or ballast pile, however, as of yet, no researchers have come close to creating a comprehensive list of the practices which can affect ballast.
Previous Ballast Studies

A frequent problem with shipwrecks is the lack of evidence related to their identity. Few ballast studies have been published, but those that are available have used ballast for two main purposes: finding clues relating to the identity of the ship or attempting to confirm the identity of the ship. The methods used to analyze the ballast range from looking for sources based on the features of the stones to examining the attached sea life in order to find a possible link to the region of origin.

One of the first detailed ballast studies was conducted by William Lamb (1988), a student at Texas A&M University for his master’s thesis. He studied ballast from the Molasses Reef Wreck (MRW), located on the southwest edge of the Caicos Bank of the Turks and Caicos Islands. Nearly 1200 ballast stones were mapped and numbered before being moved off the site for analysis. The analyses, including geochronology, geochemistry, petrography, electron microscopy, and paleontology, showed that some of the ballast may have come from sources in Lisbon, Portugal; the Canary Islands; Bristol, England; and the New World. He could not say with certainty whether the ship had physically visited the areas or if the ballast was reused at other ports.

Mapping the stones allowed Lamb to look for general features of the ballast pile such as the distribution of stone sizes and types, and evidence of stratigraphy resulting from the periodic addition of ballast as the ship unloaded cargo and replaced the missing weight. Lamb noted a potentially significant grading of stone sizes from larger to smaller in a portion of the wreck but did not see any evidence of stratigraphy (Lamb 1988:51-53, 68). Lamb (1988:67), as well as Keith and Simmons (1985:418), briefly mention the presence of coral as an indicator of interactions with the New World but do not go into further detail. Before describing his research,
Lamb (1988:5-8) briefly discussed the general features of ballast as well as some practices and factors which could influence the types of ballast that end up being loaded onto a ship. He touched on various practices including the reuse of ballast, careening, cleaning the hold, etc. but did not go into enough detail to reveal the full potential of their influence.

More recently, three different studies were conducted on ballast of 0003BUI in North Carolina, a ship tentatively identified as the *Queen Anne’s Revenge* (QAR). This ship, named the *La Concorde* prior to its capture by the pirate Blackbeard in 1717, was sailed throughout the Caribbean in search of plunder (Lawrence and Wilde-Ramsing 2001:1). The QAR sank while trying to enter Beaufort Inlet, on North Carolina’s coast. The shipwreck, 0003BUI, was located in 1996 and has since been the focus of intense research.

The first study, conducted by Callahan et al. (2001), involved using a combination of historical records and analyses including x-ray diffraction, petrographic analyses, K-Ar dating, and magnetic susceptibility tests to source ballast stones. A total of 131 stones were collected from random locations over the entire area of the wreck. Samples were also gathered from the areas in the Caribbean reported as being visited by Blackbeard aboard the QAR. Callahan et al. were able to come to some general conclusions after the comparisons were complete but could not link the ballast from the wreck directly to any specific areas. They were able to say that the ballast came from an island arc such as the islands in the Caribbean, but did not appear to match samples from areas which records point to as being visited by the QAR.

The second study, carried out by Steven Hageman (2001), involved looking at the general characteristics of the stones, recording marine organisms which had attached themselves to the rocks prior to their collection for use as ballast, identifying the organisms and their range, and using that information to build upon the potential history of the vessel. A total of 55 stones were
collected and examined. The stones were mostly rounded to varying degrees and nearly all were partially covered with a variety of encrusting invertebrates. The invertebrates were identified and all species were found to be common to a large range including the area in which the shipwreck is located. Some are found as far north as Cape Cod and as far south as Brazil; none are specific to the Caribbean or other areas of the world (Hageman 2001:70).

Based on the condition of the remains of the organisms, they most likely grew throughout a five to ten year period after the ship sank, as well as a single, more recent period during which the ballast was exposed before the wreck was reburied under sediment (Hageman 2001:72-73). Hageman also found that where multiple layers of organisms were present, the underlying remains were still those of local organisms; the stones were clean when they were first collected as ballast. A possible explanation for the shape of the stones and the lack of encrusting organisms is that the stones were collected from a high-energy environment such as a beach or river where the stones were not stationary enough for encrusting organisms to grow. In addition to preventing the growth of organisms, a river could provide a valuable source of fresh water. Hageman does not go into further detail concerning the potential human influences.

The third study, which was performed by Miller et al. (2001), involved analyzing QAR’s ballast as a means of testing the applicability of the Mossbauer Spectroscopy. This technique involves sending gamma rays through a sample (Miller et al. 2001:60). The gamma rays interact with the sample and reveal information about its composition. For this study, 29 samples were analyzed to determine their iron content. In the end, the technique did not allow the researchers to come to any new conclusions regarding the source(s) of the ballast but it was useful for characterizing and comparing samples and may prove more useful when used in conjunction with other geochemical characterization techniques (Miller et al. 2001:64).
Two studies have been conducted on the ballast from the Emanuel Point shipwrecks; one on Emanuel Point I (EPI) and one on Emanuel Point II (EPII). The ballast study on EPI was conducted by Dennis Bratten (Smith et al. 1998:66-71). He examined 46 samples of stone ballast and found that the general lithologies matched those found at a variety of locations including Veracruz, Hispaniola, and Northwestern Spain. Due to the small sample size studied, he was unable to come to any definite conclusions as to the stones’ provenance.

In 2009, Amanda Wohlberg and Dr. Chris Kelson of SUNY Potsdam examined ballast from Emanuel Point II (unpublished poster, on file at UWF Archaeology Institute). After examining samples of different rock types, they chose to analyze a piece of basalt. Thin sectioning, multi-element geochemical analysis, and Argon-Argon dating were used to identify the features of the stone. By searching the literature for geologic studies involving basalt of a similar composition and age, they found that the sample from EPII most closely matched basalts found on the Canary Islands.

These studies represent a very small portion of shipwrecks which contain ballast stones. In many cases ballast is only mentioned in passing with limited descriptions of the features of the stones. As with the outlined examples, the focus of archaeologists interested in ballast has been primarily on the features of the ballast pile with little to no explanation of how the features they were looking for were created, such as how ballast was handled while the ship was in port and on the open water, or how stone fit into the economy and interactions of both the maritime and terrestrial landscapes of the period. William Lamb (1988:5-8) briefly explains the nature of ballast with a limited discussion of various practices and terms such as “ballast broker” and “permanent ballast” with no reference to the origin of the terms. Other researchers have
mentioned possible explanations for features of the ballast and ballast pile but have not pursued them in any significant way (Bass and Doornick 1982; Callahan et al. 2001; Hageman 2001).

Research Goals

The goal of this thesis is to build on the work of previous researchers by answering a question which was not explicitly addressed in their research: “What can we learn by studying stone ballast from a shipwreck site?” The first step to accomplishing this goal is to compile and examine descriptions of any practices, both terrestrial and maritime, which would have affected the placement and types of ballast on a ship. Chapter II outlines several practices related to ballast use and trade and the extent of their effect on ballast. The archaeological effects of the practices and the potential for archaeological identification of any features within the ballast pile are examined using various shipwrecks with a focus on two sixteenth-century Spanish shipwrecks located in Pensacola Bay, Florida: EPI and EPII. At the time they sank, these two ships were taking part in an expedition to settle Pensacola, Florida.

In 1559, Tristan de Luna y Arellano led a fleet of eleven ships which set sail from San Juan de Ulúa, Mexico, known today as Veracruz, to colonize Ochuse, which later became Pensacola, Florida (Priestley 2010; Worth 2009). Ochuse was chosen for colonization by Luna and the Viceroy of New Spain after it was located during previous expeditions to the area; Luna and the Viceroy claimed the bay was well protected from the wind. Luna’s fleet set sail on June 11, 1559, and arrived on August 15 of the same year. Upon arriving in Pensacola Bay (Bahia de Ochuse) most of their supplies were unloaded from the ships and the colonists began building their new colony. At the same time, one of the ships, the San Juan de Ulua (A [A and B denote different ships which share the same name]), was sent back to Veracruz to inform the Viceroy of the successful arrival of the fleet. Just over a month later, on September 19, a hurricane struck
the fledgling colony and destroyed seven of the ten ships still anchored in the bay; six sank and one was thrown onto land.

Maritime archaeologists have found and documented two of the shipwrecks: EPI and EPII. EPI was located by the Florida Bureau of Archaeological Research in 1992 and EPII was discovered during the University of West Florida (UWF) maritime field school in 2006; the four other sunken ships and the one which was thrown inland have not been found. Both sites have been recorded and partially excavated. Along with a wide variety of artifacts, two general types of ballast have been recovered from EPI and EPII: stone and coral. Chapter III outlines the specific methods used to excavate, collect, analyze, and source stone and coral ballast from the two shipwrecks, the results of which are discussed in Chapter IV. Analyses of recovered artifacts other than ballast, along with copious amounts of research, have revealed much of what went into the expedition and what happened to the ships and the colony after the storm, but little is known about the portion of their history relevant to this thesis: where the ships came from and what they did prior to joining Luna’s fleet.

Of the eleven ships, five have partially known histories of their time before the expedition (Worth 2009). The five ships include three which were constructed in Veracruz and two ships which sailed from Spain. It is unlikely that the three ships which were constructed in Veracruz, named the *San Juan de Ulúa* (A), *San Luís Aragón*, and *La Salvadora*, were used on any other voyages and therefore have no prior history to uncover (Worth 2009:85; John Worth, personal communication 2012). The other two ships, called the *Jesús* and *San Juan de Ulúa* (B), sailed from San Lúcar de Barrameda, Spain to Veracruz, Mexico, before joining Luna’s fleet. Prior to their voyage across the Atlantic, they could have visited many other ports.
The remaining six ships, the *San Andrés, Santi Espiritu* (A), *San Amaro, Santa María de Ayuda, Santi Espiritu* (B), and the *Corpus Cristi*, were purchased, leased, or embargoed in Veracruz and do not have known histories (Childers 1999; Worth 2009:85; Yugoyen 1569). Before joining Luna’s fleet in Veracruz, these ships could have sailed to any number of ports in Spain, the Caribbean, and other areas in the network of harbors visited by the Spanish. In the future, records may be found which reveal the activities of these six ships and the two which sailed from Spain, but, for now, these are the extents of their known histories. Although UWF researchers are not completely certain of the identities of the two Emanuel Point shipwrecks, based on their size and estimated tonnage, EPI may be the *San Juan de Ulua* (B), one of the two ships which sailed from Spain in 1558, and EPII may be the *San Andrés* or one of the other ships with unknown histories.

Much of the historical information related to the sizes and origins of the ships comes from financial records, *Contaduría 877*, housed in the *Archivo General de Indias* in Seville, Spain. The compilation of these records took place in the decade following Luna’s failed expedition. During that period, Hortuño de Ybarra (1564) and Martin de Yugoyen (1569) were tasked with auditing the expenditures relating to the expedition. Included among these are detailed lists of various supplies which were purchased for the expedition as well as the merchants and captains who sold them. Through the efforts of Wayne Childers (1999), Dr. John Worth, and other researchers at UWF, the documents have been almost completely translated into English. Portions of these records relevant to this thesis are those which detail the procurement and distribution of stone for ballast. The ballast related sections are referred to throughout the remainder of this thesis.
A partial history, potential identity, and associated documentation are more than many maritime archaeologists have to work with when trying to identify or determine the context of the shipwreck on which they are working. The availability of these types of information make EPI and EPII somewhat unique among older shipwrecks and useful for comparisons between documented visits and locations pointed to by artifact provenance studies. Additionally, the ballast pile of each shipwreck displays a significantly different level of preservation; one ballast pile has remained largely centralized and potentially intact, whereas the other has eroded and spread out beyond its original boundaries.

Organisms in a saltwater environment tend to devour and undermine the integrity of exposed wood. Coupled with the slow, incessant, and abrasive movement of waves, currents, and sediment, wood can be completely obliterated in a matter of years. In most cases, including Highborn Cay Wreck (Oertling 1989; Smith et al. 1985), MRW (Keith and Simmons 1985), and many other shipwrecks, all that remains of the hull is the portion that is completely covered by ballast or sediment. The rest, including the upper and most of the lower portions of the hull, is eroded away. The rate at which wood can degrade in salt water is evident in the research and excavations conducted on the Highborn Cay wreck (Oertling 1989:247). A thin layer of sand or rock was enough to protect some of the wood, but, when left exposed by salvagers, timbers visible in photographs taken around 20 years prior to archaeological investigations were completely destroyed by erosion and marine organisms before the wreck was excavated in 1986. On all shipwrecks, when the hull is degraded enough, the contents, including ballast and other artifacts, spill out and spatial information is lost.
This is the case with EPI; the hull has eroded away to the point that ballast and other materials have spilled far beyond the extents of the hull (Figure 1). Both ships have been protected to some degree by sediments and encrusting organisms. On EPI, the preserved portion includes only the lowest section of the hull and the keel. Like EPI, the upper portions of EPII’s hull have eroded away; however, unlike EPI, enough of the lower hull remains that much of the ballast is still contained (Figure 2). This means that the ballast pile of EPII has remained more intact than those of other shipwreck sites which have been the focus of ballast studies. Other than being excavated after its discovery in 2006, there is no evidence that it has been looted or disturbed since the initial deposition and salvaging. While EPI was probably not disturbed by humans, the process of degradation has disturbed it to a large extent.

The level of preservation is also significant because all items onboard a ship had to be stowed and secured in such a way as to prevent them from shifting during a voyage (McGrail 1989; Thomas 1942). If cargo, ballast, or any large objects are not secured, their potential movement might damage or destabilize the vessel, which would put the ship and crew in danger. The need to secure material in the hold, as well as the preservation of the hull of EPII, may mean that the ballast stones are still in, or close to, their positions at the time of the expedition. When considering these factors, these sites, especially EPII, offer a unique opportunity to study the types of features that may appear in the ballast pile as a result of different practices. Chapter V discusses how the condition of the wrecks and the results of the analyses relate to ballast practices, the histories of the shipwrecks and Spanish exploration in general, and ends with the conclusions related to the potential for recovering information from ballast piles, including those of the Emanuel Point shipwrecks.
Figure 1. Site plan for Emanuel Point I. Courtesy of the University of West Florida Archaeology Institute.
Figure 2. Site plan for Emanuel Point II. The highlighted unit, 91N 492E, was excavated for this thesis. Courtesy of the University of West Florida Archaeology Institute.
CHAPTER II

BALLAST BACKGROUND

This chapter reviews maritime and terrestrial practices which relate to ballast. Although sixteenth-century practices are the focus of this thesis, very few known, contemporary records directly reference ballast or ballast practices. As a result, this chapter includes references to recent documents as well as some written as early as 400 B.C. Where records are available, references to ballast are fragmentary and it is often only mentioned in passing with little to no detail. It is for these reasons that this chapter is written as a description of practices rather than organized as a history of practices. Descriptions, definitions, and vague references are compiled in this chapter in order to create a more complete picture of the roles ballast fulfills and the practices which affect ballast, with only a few references to period-specific practices.

It is important to keep in mind that while the materials used for ships and ballast change, the basic principles of ballasting have remained the same throughout the centuries. Whether it is small stones in the bottom of a boat or water in large tanks on a modern cargo ship, ballast is there to lower the vessel’s center of gravity and make the vessel seaworthy when the cargo and other materials are not heavy enough (McGrail 1989). The need to look beyond the sixteenth century applies to ballast specific practices as well as to other practices which are not always explicitly associated with ballast but still directly affect the collection, placement, and movement of stone, including ballast, in both maritime and terrestrial contexts. The introductory chapter described the basic purpose of ballast; this chapter expands on that, beginning with a discussion of ballast materials.
**Materials Used for Ballast**

Over the centuries a few general materials have been used as ballast including dirt, stone, cement, metal, and, more recently, water. During the sixteenth century, as well as for much of the history of ship travel, the most common material used as ballast has been loose stone; the form which the stone takes can vary significantly. Stone ballast can consist of unprocessed stone of various sizes, such as sand, gravel (also referred to as shingle), cobbles, or boulders (Lamb 1988:5; McGrail 1989:357). It may seem unlikely that boulders were used, but, in geologic terms, a boulder is any stone wider than 25.6 cm; a size which is found on EPII (Tucker 2003:69). Worked stone, such as millstones or blocks, fulfilled the same need and may have been preferable as it could be worth more at any destination than unprocessed stone (Buckland and Sadler 1990:115-116). The broken remains of worked stone, or rubble, were also a viable form of ballast (McGrail 1989:357). Which form of stone was used may, for the most part, be determined by the immediately available resources and the type of cargo, but there are other factors to consider when choosing ballast.

One of the forms of stone commonly described as being used as ballast is sand (Buckland and Sadler 1990:114; Casson 1971:90; Lamb 1988:5; Laures 1986:167; McGrail 1989:357). Sand would have been, and still is, readily available on many shores. While it is probably the most easily found and accessible form of stone for a ship in need of ballast, choosing to load it into the hold of a large wooden vessel may result in potentially life-threatening problems. Sand would be kept loose in the hold on top of mats. The mats prevented loose sand from falling into the bilge where it could plug limber holes and/or damage and clog pumps (Laures 1986:167). Limber holes and pumps are necessary features of large vessels, including wooden ships of the sixteenth century. Limber holes allow water to flow to the lowest areas of the bilge; without the
holes, water would pool between the frames where it could stagnate, potentially causing the surrounding wood to rot or causing the ship to sink if it could not be removed. Pumps are positioned over the low areas near the keel into which the water flows through the limber holes (Morison 1971:135). Flowing water carried sand and any other loose material directly to the pumps.

If issues with the holes or pumps led to an excess of water in the hold, or if a storm or leak let more water into the hold than the pumps could handle, loose sand could become thixotropic (Buckland and Sadler 1990:115). This means that when wet and disturbed, such as during a storm or in rough seas, the sand acts more like a fluid than a solid and may shift, or flow, into an unwanted and unsafe position (Webster 1996:1973). The disastrous effects of shifting ballast are discussed more thoroughly in the section on stowage (2.3). To prevent sand from shifting, it could be kept in boxes or bags, although some think this is unlikely because of the additional cost of materials and because even well-constructed containers would not prevent some leakage of sand (Lamb 1988:5; Laures 1986:167). The problems resulting from sand in the bilge would not end once the ship reached port. Upon arrival, the ship would have to be thoroughly cleaned to ensure that no sand remained (Laures 1986). Any sand left in the hold and bilge could reclog the limber holes and undo any repairs that were made to the pumps, thereby placing the ship in danger, again. Sand ballast could be safely used in small, open boats with no pumps to clog or modern cargo ships as long as the hold was carefully sealed to protect the bilge (Thomas 1942:84). Despite the apparent problems with the use of sand, it was widely used by the British Navy until around 1600 at which point it was phased out for larger forms of stone (Simmons 1997:7). In large, wooden vessels, larger stones would have provided the necessary weight while avoiding the potentially crippling problems with sand.
Stones of gravel size and larger have not been described as sharing any of the problems affecting sand. In addition, larger stones, at least up to the point where a single stone could not be handled by one or two people, would be easier to move and unload than sand (Lamb 1988:6). Once placed in the hold, the stones did not need structures or containers to keep them in position and if any stones did fall between the timbers, they would be easier to remove than grains of sand. Large stones were packed tightly into place; gravel and other materials were used to fill the gaps between the large stones in order to keep them from shifting and damaging the hull. One of the commonalities larger ballast shares with sand is the potential for it to shift. While it may have taken more energy to move it from a secure position, even large ballast could shift if the ship was thrown about violently, such as during a storm (Wright 1895:418; Powers 2009:173).

Other materials are also described as being used for ballast including coral, earth, metal bars and ingots, cement, and water. Coral has been found on a few sites in the Gulf of Mexico and Caribbean; reports on the sites EPI (Smith et al. 1998), EPII (Cook et al. 2009:107-171), and the MRW (Keith and Simmons 1985; Lamb 1988) note the presence of coral among the ballast. Coral may be present on more sites, but it may not be noted if the wreck is in an area where dead coral boulders and debris are common.

Buckland and Sadler (1990:115) refer to earth (dirt) being used as ballast. The description in the source they reference does not go into detail and it is not clear whether the hold was entirely filled with dirt or whether the earth was used as a layer of soft material (dunnage) or kept in open boxes on top of the ballast (Leslie 1890:183). On an interesting side note, the exposed earth allowed the captain to do some farming in the hold of the ship when on long voyages without cargo. The possible inclusion of sand, small creatures, and organic material mean that earth may have shared some of the same problems as sand, as well as possibly producing a
runoff of mud into the bilge when wet. As with sand, dirt was a viable form of ballast aboard more modern, metal cargo ships, but issues with the inclusion of plant and animal life made it somewhat undesirable and potentially costly to the ship owner if not disposed of correctly (Thomas 1942:84).

Cement, also called poured ballast, has been recorded in some Iberian ships built during the seventeenth and eighteenth centuries (Hunter 2001:118-110; McKinnon and Scott-Ireton 2006:189-190). The cement filled what would normally be the hollow spaces surrounded by ceiling planking, outer hull planking, and frames. Metal ballast, including pig iron, lead, scrap, slag, and bars of precious metal, was not commonly used until the late eighteenth century; however, it may be present to some degree in earlier ships which carried it among their supplies and cargo (Lamb 1988:6; McGrail 1989:357). Water was introduced at end of the nineteenth century and is pumped directly from the body of water in which a ship floats. Modern cargo ships generally use water pumped into large tanks in which the amount of water can be easily adjusted as cargo is added and removed; stone and other heavy materials are occasionally used as ballast when water is not sufficiently dense (Thomas 1942: 83-84).

Of the materials described, the types most likely to have been used during the sixteenth century appear to be stones of gravel size and larger. Stones of this size range are found on sixteenth-century shipwrecks including the Padre Island wrecks (Olds 1970:60-62), the MRW (Keith and Simmons 1985; Lamb 1988), the Highborn Cay wreck (Oertling 1989), the San Juan (Audy et al. 1981), and EPI and II (EPI: Smith et al. 1998:67; EPII: Chapter IV of this thesis). The same size material was also recorded on a fourth-century B.C. shipwreck, the Kyrenia ship, and was probably widely used throughout the intervening centuries (Laures 1986:167).
The use of sand is described in literature discussing ballast, but the actual use of sand as ballast was not confirmed archaeologically as of 1986 (Laures 1986:167) and no articles published since then have archaeologically documented its use aboard early ships. On the occasions when sand found on a shipwreck was closely examined, it matched the sediment of the surrounding seafloor. A book written by Don McLellan (1944), titled *Fifty Years In Pensacola: Personal Reminiscences and Anecdotes*, describes activities on the Pensacola waterfront from the end of the nineteenth century through the first half of the twentieth century. McLellan explains how sand and stones from all over the world could be unearthed in areas where ballast had been used as fill to expand the waterfront. Among the stones was sand which had been carried from England, Wales, and Ireland (McLellan 1944:13). Given the period in which McLellan lived, the sand was most likely carried aboard a metal cargo ship.

The presence of coral is recorded at a few archaeological sites, but its use as ballast may not be explicitly noted in historical records because the portion of coral used as ballast is composed entirely of limestone (Spalding et al. 2001:34; Warner 2012:1). In addition to the book referenced by Buckland and Sadler (1990:115; Leslie 1890:183), two other documents refer to use of earth as ballast, but do not go into any detail as to the extent of its use (Maiden 1897:423; Thomas 1942:84). The other materials (metal, cement, and water) were not common ballast materials until later centuries. Although some types of ballast may be more widely used at different times, the particular materials found on any ship or shipwreck will undoubtedly vary depending on the availability of materials at the time of loading, the preferences of the captain or master of the ship, and the prevailing practices of the time. All of the material types mentioned in this section may have been carried, and thereby functioned as ballast, aboard any ship of any
period whether or not the material was actually considered ballast at the time. This last point is addressed further in the next section, which discusses different classifications of ballast.

**Ballast Classifications**

In some discussions, ballast has been categorized based on how it functions aboard a vessel. William Lamb (1988:6) describes ballast as either permanent or mobile. By his definition, permanent ballast is added to a ship upon its construction in order to provide some stability; the stones would be large and would rarely have been removed. Mobile ballast consists of small stones which could be easily unloaded when necessary. A different classification is introduced by Sean McGrail (1989:357); objects in the hold fall into two categories “saleable” and “unsaleable” ballast. The term ‘saleable ballast’ refers to cargo which acts as ballast while on the ship but can be sold at the ship’s destination. The term ‘unsaleable ballast’ refers to other objects such as rocks or sand that are loaded when the cargo is not heavy enough to stabilize the ship. This section will first address the distinction between permanent and mobile ballast.

**Permanent Ballast**

Permanent ballast is occasionally mentioned in discussions of ships and shipwrecks, but the exact meaning of the term is not clear as very few articles refer to it, and even fewer define it. The *Encyclopedia of Nautical Knowledge* defines permanent ballast as fixed or lasting, heavy material set in the hold of a ship to correct problems with stability and/or trim (McEwen and Lewis 1953: 392). David Grover (2002: 91) describes permanent ballast as being part of the designed stability of the ship and sometimes built into the ship at its construction; the materials used can include poured concrete or portable materials such as stones or pig iron. These two definitions, as well as Lamb’s, may be slightly misleading as they seem to emphasize the permanence of the ballast materials while simultaneously referring to the potential portability of
the materials and the need to occasionally remove them. A more likely meaning may be found in the discussions of Taylor (1998:116) and McGrail (1989:357) when they refer to ships as needing to carry ballast permanently. Neither of these references to ships permanently needing ballast goes into detail, but phrasing it in this way gives permanent ballast a new meaning.

If the definition is reconsidered, what is actually referred to is a ship’s permanent need for a certain amount of weight in its hold in order to remain stable; the materials which physically fulfill that need are not permanent. This is demonstrated by Grover’s (2002: 85-101) account of the attempted salvage of the Mimi after it grounded on Nehalem Spit on the Oregon coast. Shortly after emphasizing the permanence of permanent ballast, Grover describes how the salvors removed about a third of the permanent ballast in order to expedite the process of winching the Mimi off the spit. The removal of so much necessary, stabilizing weight caused the ship to capsize in the rough surf shortly after it was successfully pulled off the spit. Had the ballast been left onboard, the vessel would have been harder to pull into deeper water; however, once there, it may not have capsized quite so readily. Situations similar to this one, where insufficient ballast resulted in the loss of a ship, have been recorded throughout the centuries of sea travel.

One of the more widely known examples is the Vasa, a Swedish warship which sank when a strong breeze caused it to heel over and take on water shortly after setting off on its maiden voyage (Franzén 1960; Ohrelius 1963). After it sank, the surviving officers were called to testify in a trial held to determine the cause. The trial revealed that the ship had clearly been top-heavy; even with ballast aboard, early capsizing tests were cut short with a remark from the admiral that “she would have gone right over” if the test had continued (Ohrelius 1963:24).

When the master of the ship was questioned as to why additional ballast was not added to
compensate for the instability, he described how he carefully supervised the loading of ballast in order to ensure that the bilge was as packed with stone as was possible (Franzén 1960:10; Ohrelius 1963:23-24). According to the master of ordinance, even if there had been room, adding ballast was not an option; the lowest gun ports were only three and a half feet above the waterline (Ohrelius 1963:22).

The court attempted to assign the blame for these apparent mistakes to various officers, crewmembers, and those in charge of the ship’s construction. The officers and crew claimed that either they had done all they could or that the problems were not related to their duties; even the ship’s builders escaped blame by pointing to the king’s approval of the plans (Ohrelius 1963:25-29). Throughout the proceedings, the need for additional ballast was frequently questioned. While this was not the only issue, the inability to adequately ballast the ship played a significant role in its sinking. Given that the design of the ship clearly called for more weight, this situation could be described as the result of not just the lack of ballast, but, by the definition used in this thesis, the lack of permanent ballast.

At least one ballast-related incident occurred in Pensacola Bay and was recorded in the journal of William Henry Davison (1876; Jordan-Greene 2007:36-37), a worker at a quarantine station in Pensacola Bay during the late nineteenth century. Before passing the quarantine station, crews were required to remove all ballast from the hold of the ship and treat the empty hull with powdered sulfur. The treatment was meant to kill any harmful organisms before fresh ballast was loaded into the hold and the ship was allowed to continue its voyage. In at least one case, the removal of all the ballast was enough to destabilize a ship to the point that it capsized and sank.
There were techniques to deal with instances where stability was an issue because not enough permanent ballast could be loaded or a portion had to be removed. When ballast was all or partially removed at quarantine stations or when unloading ballast in preparation for the loading of cargo, ballast logs, also called ballast spars, could be bolted, lashed, or chained to the sides of the vessel (Liparelli 1879; Powers 2009:172; Rudder 1897:25). The buoyancy and increase in width which the logs provided was often enough to increase the stability of the vessel until the weight was replaced. Ballast logs added some stability, but if captains chose not to use them, if the logs were not attached correctly, or if rough weather hit before cargo was loaded, even ships with some ballast aboard could be capsized while sitting at the dock (Powers 2009:172-173, 175).

If the ship’s instability was the result of inherent flaws in the design which limited the amount of ballast it could hold, such as the size of the hold designated for ballast or the position of gun-ports and other features relative to the waterline, a technique called “girdling” or doubling the hull was applied, which involved attaching one or two extra layers of planking to the outside of the hull around the waterline (Ferreiro 2007:191). Girdling had the same stabilizing effect as ballast logs but would be more durable and conducive to moving through the water. Had the Vasa not sunk so shortly after setting sail, or if the instability had been acknowledged during the capsizing test, girdling may have been sufficient to prevent its sinking.

Overall, it appears the way in which the term “permanent ballast” is generally used is inconsistent and may be misleading. The distinction made by Lamb (1988) between permanent and mobile ballast may further confuse the issue. The definition which appears to be consistent with all references to ballast, whether explicitly described as permanent or not, is the one described earlier which links the permanency of the term “permanent ballast” to the design of the
vessel rather than as a description of the ballast. To take this one step further, it could be argued that the original definitions of the term “permanent ballast” are not entirely applicable when referring to early ships using loose stone which was not fixed and could be replaced on a somewhat regular basis. All types of loose stone ballast simultaneously fulfill the permanent needs of the vessel while remaining mobile enough for the crew to unload.

On any ship, there may have been ballast which remained onboard for long periods of time without being permanent. This ballast, which could include any or all of the materials discussed in section 2.1, could remain in the hold for months or years, but when the area containing the ballast needed to be cleaned or filled with other material, for reasons to be outlined in section 2.5, the ballast had to be removed and replaced with clean ballast or cargo. There were types of ballast that may have remained permanent out of necessity. Among the earlier forms of ballast, materials adopted later, such as poured cement and metal, most closely approach a permanent role as ballast. The removal of poured ballast probably required the crew to partially dismantle planking on the inside or outside of the hull. This probably would not have been done very often and the ballast would be fixed in place by the frames and planking in the interim. Metal would be somewhat less permanent as it would still have to be removed for the purposes of careening and cleaning the hold; however, it would be easy to clean and would probably not be abandoned for clean material except possibly in port.

In short, ballast was not loaded unless necessary and it was not uncommon for ships to unload more ballast than was safe in preparation for the loading of cargo or cleaning the inside and outside of the ship. It could also be argued that they were only removing what Lamb (1988:6) referred to as mobile ballast, but, if that were the case, the ship’s stability would not need to be reinforced with logs or other structures. Ships without sufficient ballast would
probably respond in much the same way as the *Vasa*. They would be stable while at rest in a protected body of water yet be liable to capsize if placed under even slight external forces. As the next section illustrates, the weight which fulfilled the ship’s basic ballast needs could come from anything placed aboard the ship, including ballast, cargo, supplies, and ordnance.

*Cargo as Ballast and Ballast as Cargo*

Once an object, regardless of its size and composition, is placed on or in a vessel, it is factored into the allotment and distribution of weight aboard a ship. This is effectively demonstrated by Sean McGrail’s discussion of “saleable” versus “unsaleable” ballast (McGrail 1989:357). He classifies cargo as saleable ballast; it is loaded for the purposes of trade, yet while aboard it fulfills a portion of the ship’s ballast needs. The remainder of the necessary weight is composed of what McGrail refers to as unsaleable ballast: rubble, gravel, sand, or other forms of unprocessed or reclaimed stone. This classification is useful for illustrating the multiple functions a single item has once aboard a vessel, but it may be slightly misleading because, depending on the destination, stones and other materials used as ballast may be valued as building materials, or, at the very least, can be used as fill or reused as ballast (Buckland and Sadler 1990: 115; Lazareth and Mercier 1999).

The audit records of the Luna expedition offer an excellent example of stone being both ballast and cargo. An excerpt from the records translates as: “For a bark-load of ballast that weighed 7½ tons for the said ships of the armada that he brought from Villarica la Vieja to the said port at 120 pesos” (Yugoyen 1569:544; translation from Childers 1999:244). In the passage, “he” refers to Jhoan Pérez, a sailing master from Portugal. Pérez’s ship transported close to 31 tons of goods including ballast, salt, a padlock, empty casks, empty chests, and sweet cane from Villarica la Vieja, which is known today as Punta Villarica, Mexico. Had the ship carrying the
stone sunk, and if it was not carrying the other items, it would most likely be described by archaeologists as being “in ballast,” meaning it was not carrying any cargo (McEwen and Lewis 1953: 32). This would not be entirely true because seven-and-a-half tons of the ballast was actually cargo. No other records describing the actual shipping of stone for ballast were encountered in the research for this thesis, and for good reason. In nearly all situations, the movement of ballast was probably not a priority and any sale of it could have simply been an unplanned transaction resulting from changes in the demand for stone at a port.

Ideally, all the materials used as ballast would be of some value to the people at the current destination or valuable in the general economy and therefore potentially tradable at a future stop (McGrail 1989). As the previous example shows, it was possible that loose, unprocessed stone ballast would be of use in a particular port, however bars of metal or large, functional pieces of stone would be both more dense and more valuable (Buckland and Sadler 1990:115-116; Lazareth and Mercier 1999; McGrail 1989:357; Yguyen 1569:544). Ingots and other higher value ballast could have been kept aboard the ship until they could be sold and replaced by other dense, saleable objects. Rather than being carried to a particular destination, high value ballast could be carried indefinitely, until a buyer was found. Archaeologically, this ballast might be indistinguishable from cargo even though its role aboard the ship may have been closer to that of ballast until it was sold. A seventh-century Byzantine shipwreck off the coast of Turkey, the Yassi Ada wreck, demonstrates the dual-function and advantage of dense cargo (Bass and van Doornick 1982).

The Yassi Ada wreck was loaded with amphorae, amid which only a small amount of ballast was found (Bass and van Doornick 1982:63-64). The ballast was located on the port side of the vessel, near the keel, and weighed only a few hundred kilograms. Such a small amount
would not be sufficient to ballast the ship and may instead have been acting as a stabilizer for the
cargo around it, or as a small adjustment to the trim of the ship. The lack of ballast can be
explained by the presence of the amphorae. The amphorae and their contents were dense enough
to adequately ballast the ship while providing the owners with a source of income upon arriving
at their destination without wasting space in the hold. Had the amphorae been less dense, more
ballast would have been loaded. Most ships and shipwrecks may not show such a high ratio of
cargo to ballast; however, the amount of cargo always influences the amount of ballast. In the
following discussions of ballast and cargo, it can safely be assumed that general references to
ballast can also refer to cargo and vice versa as both share the same function while in the hold.

*Stowage and Ballast Placement*

When an object is loaded onto a ship, the crew must securely stow it and all other
material before going to sea. This process is referred to as stowage. In *Oeconomicus*, a socratic
discourse written around 400 B.C., Xenophon discusses a conversation with a Phoenician ship’s
crewmembers in which he comments on the neatness and amount of attention paid to keeping
everything in the holds orderly and easily accessible (Strauss 1998:38). The same passage is
referenced over 2300 years later in a book written by Robert E. Thomas (1942:3), titled *Stowage:*
*The Properties and Stowage of Cargoes*, which discusses the importance and process of stowing
cargo of various types as well as the proper ballast material to use in different situations.

Thomas’s book is focused on outlining the procedure for stowing cargo in modern cargo ships,
but, as with the function of ballast, the basic principles have remained the same throughout the
centuries and can be applied to ships of all periods. For example, securing ballast and cargo is
just as important in modern ships as it was aboard ships of the sixteenth century and earlier.

Although modern cargo ships usually have a system for pumping water in and out of tanks, solid
ballast is occasionally needed to give the vessel a deeper draft (Thomas 1942:83). In ships of all periods, solid ballast could shift and damage the ship and cargo or kill crewmembers working in the lower decks and holds. A shift in the position of ballast could be enough to upset the trim of the vessel, thereby causing it to list and potentially capsize.

How and where ballast is stowed on a given vessel is determined by its design. Vessels with an open deck, as in canoes or small sailboats, kept ballast directly on the deck (Agius 2008:123). Larger, enclosed vessels, such as the Yassi Ada wreck, stored both ballast and cargo in the same hold (Bass and van Doornick 1982). Much larger vessels with multiple enclosed decks, like the Vasa, had a specific hold which was filled with ballast (Franzén 1960; Ohrelius 1963). There may be other, slightly different arrangements for the storage of ballast, but these three appear to represent the most common layouts. Aboard larger ships, materials called dunnage were placed around the ballast and cargo to hold it in place and protect the hull from chafing and other damage. Dunnage consisted of wood chips, hopleaves, moss, straw, grass, boards, or other objects which could fill the spaces between loose items (McEwen and Lewis 1953:144-145; McGrail 1989:357).

The master of the ship is responsible for making sure everything aboard the ship is properly stowed, secured, padded with dunnage, and accessible when needed (Palacio 1966: 140). The master was also given the title of captain as a courtesy aboard merchant and fishing vessels when the owner of the ship, who was usually the captain, was not present; aboard Navy vessels, the officer in charge of the vessel was referred to as the captain (McEwen and Lewis 1953:71, 332; Palacio 1966: 140). On larger vessels, the responsibility of stowing certain types of items may be split up among a few officers; the Vasa had a Sailing Master in charge of stowing ballast and cargo, as well as a Chief Ordnance Officer responsible for the proper
securing of cannons and ammunition (Franzén 1960; Ohrelius 1963). The particular titles may vary somewhat by nation and period, but, in all accounts, it appears to be the responsibility of the master to verify that ballast and some, or all, other items aboard the ship are secure and in their proper place.

The items within the master’s purview also include tools and objects which may be required to repair or replace vital parts of the ship (Strauss 1998:38-39; Thomas 1942:3). The individual items may not be big enough to upset the trim of the ship if they fall out of place, but they had to be properly stowed in order to limit the amount of time spent retrieving them. Searching for a misplaced part, rather than knowing exactly where to look in the middle of an emergency situation, could mean the difference between sinking and continuing the voyage. Keeping items easily accessible for potential incidents is important, but the long-term plans of the ship, as in where it plans to stop on its voyage and what will be loaded or unloaded at each port, also influence the manner in which items are stowed.

In order to prevent from unnecessarily unloading cargo, as well as saving time and money, it is necessary to plan the stowage of items with the pending stops for the ship in mind. The order in which certain pieces of cargo will need to be accessed influences their placement (McGrail 1989:356; Thomas 1942:5). As plans for subsequent stops are changed or added, cargo may need to be rearranged to allow for easier unloading at earlier stops in the next portion of the voyage. Stowing items in the hold, and rearranging them, could not be done without considering the distribution of ballast and other cargo. Making a large, dense piece of cargo more accessible may unbalance the vessel unless ballast, or another object, is positioned so as to offset the weight (McGrail 1989:356).
Moving ballast to compensate for cargo may mean that ballast is not spread evenly throughout the ship; it is placed where it is needed to balance the ship and maintain the proper trim (McGrail 1989:357). A good example of this can be seen on the Yassi Ada wreck (Bass and van Doornick 1982). As discussed earlier, the ship only had a few hundred kilograms of ballast stone which was loaded in a single area, on one end and side of the ship. Even a ship travelling in ballast would not necessarily have evenly distributed ballast. Extra weight may be needed in one area to compensate for any superstructure or fixed mechanisms on the opposite side of the ship.

Additionally, when moving or stowing ballast and cargo, each item had to be positioned relative to other items in such a way as to account for the qualities of each item. The size, density, fragility, and/or susceptibility to moisture, had to be considered to prevent damage and loss as a result of cargo being broken, crushed, contaminated, or exposed to other stresses which a particular material could not handle (Thomas 1942:5-20). These characteristics, as well as all the previously outlined factors, make stowage a more complex task than it may seem at first glance. Items cannot simply be loaded wherever they fit or where the weight is needed. Once the process of stowage was completed, weight should be properly distributed throughout the vessel and all items should make it through the voyage without being damaged.

Even when the master has achieved the ideal arrangement of cargo and distribution of weight, the items in the hold could not always be left in place. This point was partially addressed earlier in this section with a description of the necessity for rearranging ballast and cargo while loading the ship in port, however, the need to rearrange items can also arise while a ship is in open water. The necessary movement of ballast is especially apparent in small boats and canoes where a single person can change their position within the boat in order to stabilize it when the current or wind shifts. For the same reasons, slightly larger boats, including small sailing vessels,
may need ballast and cargo to be moved to different areas of the deck multiple times during a single voyage (McGrail 1989:357). Crews aboard large ships must also shift materials while underway in order to maximize the ship’s movement through the water in different conditions; this has been described as impractical but is still occasionally necessary (McGrail 1989:357).

An account by William Hutchinson (1970:70) describes the movement of objects in the hold, while at sea, in order to change the trim and shape of the ship and make it move through the water more efficiently. A ship’s shape can be influenced by the distribution of weight; if too much weight is placed amidships or at the bow or stern, the hull can flex. The shape of the underwater portion of the vessel is also affected by the rolling, or tilting, of the ship which can be remedied by correctly ballasting the ship and increasing its stability (Ferreiro 2007: 177). Ballast moved to adjust the trim is called shifting-ballast (McEwen and Lewis 1953: 32).

An analogous tuning of forces, which may clarify the previous point, is used to make planes fly. The wings of a plane are shaped to allow air to flow around them in such a way as to generate lift and carry the plane into the air. Flaps on the back of the wings allow the pilot to influence the flow of air, thereby moving the wing in the desired direction. On a ship, the rough equivalents to the wing and flap are the hull and rudder, respectively. Where a wing is meant to generate a force in a particular direction (lift), a hull is meant to split the forces equally to either side. Just as with a wing, a hull which is not shaped correctly will not move through its intended medium as intended. In other words, any unevenness in the force of water on the hull will produce drag and slow the ship down. The master of the ship would most likely do his best to prevent the need to shift weight while underway by carefully loading items and checking the trim of the ship, but even a skilled master could make mistakes.
The ultimate goal of stowage is to achieve the proper freeboard, draft, stability, and trim (as outlined in section 1.1) while keeping all the issues discussed in this section in mind (McGrail 1989:354-355). Failure to do so could result in the loss of anything from a few pieces of cargo to the entire ship and crew. However, ballast was not always arranged to keep large ships in a normal, upright position. Occasionally, the need arose to distribute weight unevenly in order to heel a ship to one side for the purposes of careening.

Careening

Careening is the process by which a crew would expose the bottom of their ship in order to make any necessary repairs to the hull and clean away organisms which affect the ship’s speed and maneuverability (Goelet 1986). In his master’s thesis, Michael Goelet discusses various careening methods which can be narrowed down to two general categories: a ship could be pulled ashore where it would lay on its side, or it could be heeled (tilted) over to expose the lower portions of the hull and the keel while afloat. Careening a ship on land, whether on the beach or the shore of a tidal waterway, involved the use of wooden blocks, a wooden framework, or a bare shore which would be exposed at low tide (Goelet 1986:1-3). This method was primarily reserved for smaller ships which were less likely to be damaged by their own weight and sharp objects hidden by mud or water; however, even large ships would have to careen against the shore if they were traveling alone (Goelet 1986:25).

Whenever possible, larger vessels were careened while afloat by securing them to a stable platform, which could be the shore, a dock or wharf, or a heavily ballasted vessel such as a barge or small ship of the line adapted specifically for careening; the latter having been stripped of rigging and filled with ballast (Goelet 1986:13-14, 25-26). Depending on the exact method used and the extent of the cleaning and repairs, nearly all elements of a ship, from the top of the
rigging to the waste in the bilge, could be affected during the process of careening. The methods varied based on the size and design of the ship, the available resources, as well as the preferences and nationality of the captain. Regardless of which method was used, it was necessary to prepare the ship to some degree.

A relatively limited type of careening performed on a floating ship was called a parliamentary heel, or media carena in Spanish, and was routinely performed to expose the portion of the hull just below the waterline in order to complete regular maintenance (Goelet 1986:13, 15). Preparing for a parliamentary heel involved moving ballast and other objects over to one side of the ship, thus offsetting the center of gravity and causing the ship to tilt. The area around the waterline on the lighter side of the ship was exposed, cleaned, and repaired. A parliamentary heel may not involve the disturbance of all the ballast in the hold; it may be only the topmost, immediately accessible portion that is shifted from side to side while leaving the lowest portions of ballast in place. Other types of careening entailed the complete exposure of one side of the hull and also required much more preparation. Careening a ship on shore involved removing the ballast and other loose objects within the ship; if left on board, objects might shift and damage the ship (Goelet 1986:39). When on shore, the weight of heavier objects like ballast and ordnance would have put an immense strain on the hull of the ship. Even the weight of the ship could be enough to damage itself if the ship was large enough. For this method of careening, the rigging could be left intact as the ship settled onto its side or onto blocks which held it clear of the water as the tide receded.

Careening a floating ship was a more delicate procedure potentially requiring the removal of portions of the rigging as well as the construction of additional structures in and on the hull and rigging which aided in heeling over the ship (Goelet 1986:45-46, 55-114). The same
structures were also used to maintain the stability of the heeled ship to prevent it from either heeling too far and taking on water or putting too much stress on the rigging and causing a potentially catastrophic failure of the rigging and careening gear; either of these issues could result in the loss of the ship. This stress was partially controlled by leaving enough ballast aboard the ship to stabilize it; the rest of the ballast was removed along with all loose items (Goelet 1986:39). The ballast which remained on board was not left in its usual location along the keel; it was placed at the turn of the bilge, the lowest part of the ship during careening. Securing the ballast was essential in order to prevent it from shifting and putting additional strain on the ship and the careening gear. The ballast was secured using “pouches” consisting of wooden bulkheads added by carpenters (Goelet 1986:45).

Beaching a vessel or modifying it and its rigging and putting the ship in a heeled-over position left it very vulnerable to outside forces including hostile ships and unforeseen changes in weather and water conditions (Goelet 1986:23). If a crew with a careened vessel was caught unaware, their ship could be attacked and/or damaged and, in the worst cases, lost to the sea or captured. In order to protect the ship, a sheltered, defensible location would be chosen. When careening smaller ships in a tidal river, the river and the surrounding landscape could provide some protection from the weather and hostile ships and soldiers who would be limited in how they could approach the careened vessel and its crew. In the same way, a harbor would provide a level of defensibility not available on an open beach. The ideal types of locations for careening are relevant to a discussion of ballast because the locations which were chosen would affect the rock types which were loaded onto a vessel as fresh ballast.

Once the crew had found a location and fully prepared, heeled, and stabilized the ship, they would have access to the area of the hull around the keel, inside and out. The removal of
ballast exposed the bilge, where all the waste collected while the ship was at sea. While some of the focus of careening was on the outside of the ship, what the crew did inside may have been just as important in terms of the health of both the ship and its crew. As the next section will make clear, cleaning out any waste which had built up in the bilge was an unpleasant yet essential task.

Cleaning the Hold and Ballast

Cleaning out the hold is a comparatively simple, yet important practice. A ship’s hold had to be cleaned, because over the course of a voyage, human and animal waste could be continually accumulating in the bilge from cooking (Lenihan 1983:61), bodily excretions (Simmons 1997:6-7), livestock (Leslie 1890:176-183), pests (Shidner 2011), and deceased crewmembers (Simmons 1997:8). These sources of waste, combined with a damp environment with limited airflow, could lead to the creation of an unsavory and potentially dangerous environment within the ship (Simmons 1997:6-7). According to a sixteenth-century account by Dr. Diego García de Palacio (1986:137), the buildup of gases given off by waste could, and did, have deadly consequences for crew members that entered the lowest areas of the hold to perform tasks like cleaning around the base of the bilge pumps. Allowing the conditions in the hold to deteriorate to that degree could be harmful in other situations as well.

Depending on the size and layout of the ship, it could be necessary for the crew to use the hold as their sleeping quarters in inclement weather, rather than sleeping on the deck (Arnold and Weddle 1978:84-85). After the addition of the forecastle, this may not have been as much of an issue for the crew, but if passengers were taken on board, some may have been forced to sleep on the ballast if other arrangements were not available. Additionally, the layout of the ship may require most, or all, of the ship’s supplies, including food and other provisions vital to the
livelihood of the crew, to be kept in the hold with the ballast and cargo. If noxious gases or waste had built up, bacteria and pests could thrive, contaminate the provisions, and endanger the crew, passengers, and those to whom the cargo was to be delivered.

Like so many shipboard practices, the manner in which the hold was cleaned and/or disinfected undoubtedly varied depending on the context of the cleaning which would also have affected the available resources. In the description by Palacio (1986:137), before going into a pump-well which may contain bad air, the crew was advised to place a lantern containing a lit candle and wait until the candle burned itself out. If the candle went out prematurely, the air in the well was corrupt and liquids including vinegar, urine, and cold water were thrown in to clean the air and remove any dangerous gases and organisms. At the Pensacola quarantine station, mentioned earlier, powdered sulfur was applied to the entire interior of the ship after all the ballast was removed (Davidson 1876). Other quarantine stations were experimenting with carbolic acid and solutions of bichloride of mercury dissolved in muriate of ammonia (Holt 1892:42-43). In remote locations, where chemicals were not available unless they were included in the supplies, cleaning the hold may have involved removing as much filth as possible and scrubbing the accessible areas.

How much effort a crew would put into cleaning ballast once it had been taken from the hold, rather than collecting fresh materials, is unclear. The purpose of removing the ballast appears to primarily be for the preparation and treatment of the hold and hull with little or no attention paid to the ballast beyond taking it off the ship. Ballast removed from a polluted hold could have been sitting in waste for an extended period of time, weeks, months, or years depending on the length of the voyage and the frequency of careening and hold cleaning. Porous
materials such as coral and vesicular basalts, which are found on the Emanuel Point shipwrecks, may be permeated by waste and difficult to clean.

The degree to which fouled ballast was dealt with most likely depended on where a ship stopped and the condition of the hold required to maintain the integrity of the cargo and supplies. When cleaning the ship at an uninhabited location, ballast stones could be removed from the hold and either discarded or placed in the tidal zone to be cleaned; as the tide rose and fell the action of the waves and currents scoured the stones of clinging filth (Morison 1971:135; Simmons 1997:7). Any stones which were discarded or not recollected from the tidal zone could be replaced with new stones. When entering a port, replacement ballast may have been more readily available, making it easier for the captain to simply discard the fouled stone in favor of fresh material. Regardless of where a ship stopped, any waste in the hold or on the ballast could contaminate the cargo. This could be a significant factor when the captain has to decide whether to reuse the current ballast or attain fresh material after cleaning the hold. The only viable option to adequately clean the hold and keep out all fouled material may be to discard certain, or all, types of ballast.

**Discarding Ballast**

The previously discussed practices, careening and cleaning the hold in particular and stowage to a lesser degree, involve removing ballast from the hold and partially or completely discarding the fouled stone before loading fresh ballast and/or cargo. In certain environments, where ballast was discarded was just as important as where it was gathered. In uninhabited areas, carelessly dumping ballast may not have been an issue. In heavily trafficked ports and harbors, if ballast was not discarded in an organized fashion, as in dropping it in a single, specified location...
which could be marked on a chart, a harbor may eventually become impassable as it fills with discarded ballast (Lazareth and Mercier 1999:123; Lindroth 1957:158).

To prevent this from occurring, laws, rules, and ordinances were often enforced by those in charge of a port. Such was the case at the founding of Newfoundland’s first permanent settlement in the early 17th century (Lindroth 1957:157-158). A rule was enacted stating that ships would be penalized for throwing ballast overboard and should instead carry it onto shore. This was also a problem in Pensacola Bay; fines were issued to those that chose to ignore the rules (General Assembly of the State of Florida 1855:23-29; Kennedy 2002: 232-233). Prior to the creation and enforcement of these laws, ballast was dumped in the water which resulted in piles that still exist in many areas of Pensacola Bay. A thorough study of any active port will most likely reveal similar laws, as this would have been a problem wherever ships had to stop and take on cargo.

The removal of ballast from ships in ports and harbors has been handled by a few different groups over the centuries; except for the differing arrangements surrounding their employment, they all appear to have shared essentially the same job as stevedores who, by definition, have the job of unloading and loading ships (McEwen and Lewis 1953:537). For example, in a description of the movement of grains through Portland, Oregon, additional costs to incoming ships are also outlined; among the various fees for pilotage, lighterage, towage, and the acquisition of provisions, a section detailing the costs of discharging, hauling away, and acquiring “good ballast” is included along with a list of charges for having stevedores move different items (Industrial Commission 1901:104).

A few other terms for ballast handlers have been encountered throughout the course of this research. In 364 A.D., ships entering Rome’s harbor, Portus, were required to hire *saccarii*
from the official guild to unload their cargoes; *saccarii* translates as “sack-men” and appears to be the equivalent of the stevedore (Casson 1971:370). Also operating in Portus, as early as 210 A.D., and possibly sharing a close relationship with the *saccarii*, was the “*corpus saburrariorum*,” or “guild of ‘sandmen’” who handled ballast in the port (Casson 1971:370).

More recently, a report for a quarantine station located on the Port of Savannah, Georgia in 1894 mentions the use of “ballast hands”; their exact job is not made clear, however, they appear to at least be responsible for hauling away ballast discharged in preparation for the fumigation of a vessel (Graham 1894:199). In many cases, the same individuals who unloaded the ballast were most likely also responsible for hauling it away and bringing in fresh ballast. Where ships and these dockside workers could have acquired fresh ballast, as well as the uses for the discharged stone, will be discussed in the next section.

*Sources and Other Uses of Stone*

When a crew found their vessel in a situation where adding ballast was necessary for the continued, safe operation of the ship, such as after careening, cleaning the hold, offloading cargo, or before loading a light cargo, the crew had to rely on local sources of ballast material. These sources could take many forms; anything from a broker or merchant selling stone to a dilapidated structure or cobble beach could provide adequate ballasting material.

Where a particular ship would acquire ballast depended on various factors, the most immediate being whether or not they were at a location with port facilities. A ship which was not within range of a port would be forced to rely on natural sources including beaches, rivers, or eroded stone outcrops; which source environment was utilized would ultimately depend on the local geology and geography as well as the needs of a master and his ship. For example, the need for fresh ballast may have been one of the factors influencing which location was chosen for
careening. As discussed earlier, this delicate procedure needed to be performed in a protected location so as to prevent the loss of a vulnerable ship at the hands of attackers or as a result of unexpected changes in weather (Goelet 1986:23). In addition to seeking a sheltered cove or harbor, a master may have surveyed the shore for adequate ballast material in order to prevent reusing the fouled material being removed from the hold.

Hengistbury Head of Dorset, England is an example of a sheltered location frequented by mariners. The north shore of Hengistbury Head is also the south shore of Christchurch Harbor. The mouth of the harbor is almost completely closed off by the Mudeford Sandbank. The result is a protected harbor which has been settled as far back as the Upper Paleolithic (Taylor 1998:113). A site on the north shore of Hengistbury Head contains the earliest known archaeological evidence of a ballast quarry. The site contains ‘scoops’ in a gravel shoreline dating to the early first century B.C. (Taylor 1998). These scoops are located along what was a landing site used by vessels to unload cargo and take on ballast and/or cargo for the return voyage. The gravel shoreline presented a convenient source of ballast without the need to transport the material long distances while the harbor itself offered a protected body of water in which the unloading of cargo and other tasks could be performed in relative safety.

The shoreline represents what is called a high-energy environment; waves and currents are continually moving stones and grinding them against each other as well as other sand and debris. The result is an area containing stones on which the edges are worn down and rounded. Other studies also point to high-energy environments as sources of ballast stone; when choosing ballast, rounded stones were desirable because, if they shifted, they would do less damage to the timbers in the hold of a ship than unworn stones with sharp edges (Hageman 2001:72; Hoare et al. 2002:101; Lamb 1988:5). Certain locations may offer ballast with other important qualities as
well as other resources. For example, the fast moving water in a riverine environment could smooth the edges off stones and keep hard-to-remove organisms, such as barnacles or mollusks, from growing on the stones. If rocks covered in organisms are placed in the hold, the organisms may rot and negate the time and effort spent gathering fresh material. The river could also serve as a source of fresh water which could not be replenished while at sea (Hageman 2001:72).

Crews gathering ballast in remote locations were not always limited to natural sources of stone. In some cases, formerly inhabited structures which had fallen into disrepair could serve as a convenient, free source of stone ballast. Kisimul Castle, which is located directly adjacent to the water, on a small, rocky islet in the middle of Castle Bay of Barra, Scotland provides an excellent example of the effect crews in need of ballast can have on a structure (Miers 2008:355-357). Kisimul castle was probably built in the early- to mid-fifteenth century. It was expanded upon until the seventeenth century, abandoned in the early eighteenth century, and burned in 1795. During the herring boom of the late nineteenth and early twentieth century, local fishermen took stones from the castle to use as ballast. In the process, most of the buildings within the castle and the curtain wall surrounding the castle were dismantled. Castle Bay has actually been inhabited since at least the Iron-Age, but Kisimul Castle is still a good example of the lengths crews will go to in order to take advantage of a convenient source of stone even if the source is a castle directly adjacent to a functioning port.

In an active port, a ship’s master would have a different set of sources at his disposal. There appear to have been two main sources of ballast in busy ports: individuals or groups who sold stone and merchants who included stone among their wares. In most cases, those selling stone probably dealt directly with the Captains and Masters to which the stone was sold. However, it appears that in some ports, the parties selling stone may have sold it through the
local government at a specified price. Such may have been the case in Portland, Oregon at the
to the beginning of the twentieth century. A Master in need of “good ballast” would pay “from 60 cents
to 75 cents per ton of 2,240 pounds” (Industrial Commission 1901:104). The specific
measurement of the tonnage was important because other tasks, such as hauling away discharged
ballast, were charged at a rate measured “per ton of 2,000 pounds” (Industrial Commission
1901:104).

At least two different names have been given to the individuals and groups who collected
stone and sold it to ships. The oldest known example of a group collecting stone and selling it as
ballast can be found in inscriptions from Portus, Rome’s harbor. An inscription dating to 210
A.D. refers to a notice which had not yet been posted; the purpose of the notice would be to mark
a certain area from which material could be collected by the “corpus saburrariorum”, or “guild
of ‘sandmen’” (Casson 1971: 370). The guild was composed of saburrarii, which translates as
“sandmen” (Casson 1971: 370). The saburrarii are described as gathering sand, but, for the
reasons discussed earlier pertaining to the problems with sand, it seems more likely that they
were gathering gravel (Laures 1986:167). Some of the confusion may lie in the actual meaning
of the term saburra; it is often described as meaning sand but may actually translate as gravel
(Laures 1986:167; Williams and Moore 1995:511). Over time, “ballast” may have been added to
the possible meanings of saburra as a result of a common usage of gravel as ballast (Laures
1986:167). The saburrarii appear to be somewhat unique when compared to later references to
ballast sellers. Whether or not they were dealing primarily with material to be used as ballast,
their sole occupation appears to be the gathering of sand and/or gravel. This is also illustrated by
the necessity of the saburrariorum to which they belonged.
Another term for ballast sellers is not nearly as specific. William Lamb (1988:6) refers to those who handle and trade in ballast as “ballast brokers.” The problem with this term is that it may be overly specific. More accurate terms may be “stone brokers” or “stone merchants.” Those selling stone as ballast were not limited to trading with ships and were most likely also trading with merchants and contractors who were purchasing material for the construction of buildings, roads, and other structures for which loose stone could be used (Lazareth and Mercier 1999; McLellan 1944:13). In many cases, even the terms stone broker and stone merchant are too specific because they imply that those selling stone only dealt in stone. Although it is a very general term, “merchant” may most accurately describe many of those who sold stone for ballast.

The applicability of the label “merchant,” as opposed to the other, more specific labels, is demonstrated by accounts of land-based activities related to ballast as well as the records associated with Tristán de Luna’s expedition.

One recent account, which describes activities on the Pensacola waterfront in the early twentieth century, demonstrates the parties to which ballast could be sold, the many uses of the stones, as well as the multiple roles of those selling ballast. A man named Captain E. E. Saunders, who owned a fish company of the same name, was able to get rich by charging ship captains a fee to have his men remove ballast from ships; Saunders then sold the stone to local contractors for construction (McLellan 1944:12-13). Stone gathered from ships was used as fill material as well as to build roads and buildings including the Pensacola hospital. Although it is not mentioned, some of the stone taken from ships was probably resold as ballast. Port cities around the world contain structures built with discarded ballast stone including San Francisco, California (Powers 2009:45), Pensacola, Florida (McLellan 1944:12-13), Brouage and La Rochelle, France (Lazareth and Mercier 1999), and King’s Lynn, Norfolk, UK (Hoare et al.)
An examination of historic documents from other ports and seaside cities would undoubtedly reveal the reuse of ballast under similar circumstances.

The reuse of ballast may have been most prevalent in ports where laws had been enacted which required the ballast to be offloaded onto land (described in section 2.6). This would give land-based entrepreneurs direct access to the stone without having to go through the potentially costly process of recovering it from the bottom of the harbor or transporting it in from other areas. Just as with crews looking for ballast, the merchants undoubtedly utilized convenient sources of stone whenever possible. Even though discharged ballast probably represented a more or less constant influx of stone, it was still necessary for merchants to rely on other sources if the demand for ballast and/or building material exceeded their current supply. Merchants most likely collected stone from sources similar to those utilized by crews or voyaging ships (i.e. beaches, rivers, outcrops, abandoned structures), but, because those working from shore may have had the time and resources available to allow them to range inland or farther along the shore, the stone they collected could come from many more locations. Stone from external sources could have easily become mixed with the stone from ships. The records from the Luna Expedition reveal the necessity to look beyond local sources for supplies of ballast stone.

Spanish accounting documents linked to Luna’s ships describe the purchasing of ballast from merchants (Yugoyen 1569). On at least one occasion, over seven tons of stone to be used as ballast was shipped from Punta Villarica, a settlement located on the coast approximately forty miles northwest of Veracruz (Childers 1999:244; Yugoyen 1569:544). Another forty-seven carts of stone were hauled from La Antigua, which is located about nineteen miles northwest of Veracruz and was named Veracruz prior to 1599 (Yugoyen 1569:50). There is no reason to think the long-distance transportation of stone was limited to this occasion, although in some ways the
situation may have been unusual. Since it may have been necessary to partially or completely clean and reballast all eleven ships in preparation for the loading of food, livestock, and people, more fresh stone may have been needed than the local suppliers could handle. The same merchants sold much more than just stone; they also sold other items including salt, casks, and chests to the officials organizing the expedition (Childers 1999:244; Yugoyen 1569:544). It is unclear whether the stone sold as ballast was saved by the merchants specifically for that use or for another purpose such as constructing houses and other structures.

Once stone has been unloaded from ships or transported from inland areas, the manner in which the stone was stored came down to the amount of available space and the use for which it was intended. If it was meant to be used as ballast, it was most likely stored in piles on the wharf or foreshore (Hoare et al. 2002:104), or, as the Luna documents show, kept elsewhere in the city and carted to the port as needed (Childers 1999:174, 188, 238, 239). The exact placement undoubtedly depended on the layout of the docks and structures immediately adjacent to the port. Stone collected for other purposes may have been kept elsewhere, inside or outside the city, and used as ballast when supplies at the port were not sufficient.

If stone stockpiled for purposes other than ballasting ships was used as ballast, it may have resulted in the introduction of rock types which would not normally be used as ballast. In particular, the coral found on the shipwrecks may have only ended up in the ballast after being gathered for construction. Large pieces of coral are clearly visible in photographs of the House of Cortez and the Fort at San Juan de Ulua (Figures 3-5). The porosity of coral would make it more difficult to clean. This applies to attempts to clean it when removing it from the hold and before placing it in the hold. When collecting ballast from a beach environment, coral may have been avoided by ship captains because any encrusting or imbedded organisms could die and rot once
Figure 3. House of Cortez. Photograph by Dr. John Worth.
Figure 4. Close-up of wall of House of Cortez which includes coral, stone, and brick held together with mortar. Photograph by Dr. John Worth.
Figure 5. The wall of the Fort at San Juan de Ulua which includes coral, stone, and brick held together with mortar. Photograph by Dr. John Worth.
the coral was removed from the water and placed in the hold. However, any coral which had been sitting on land for an extended period may have been washed clean by the sun and rain.

The same natural processes may have served as an inexpensive means of cleaning other types of stone as well, particularly when the stones were taken from the hold of a ship. This may have resulted in an undocumented and indeterminate transition period during which fouled ballast was left in the open. The stones may have also been placed in the tidal zone for a short time in order to wash off filth, just as some ships did when away from port (Morison 1971:135; Simmons 1997:7). Leaving the stones in the water for too long would allow organisms to grow in and on them, thereby undoing any cleaning efforts. It may be that in situations where stone was to be reused, the first stones chosen were those which had been sitting in stockpiles long enough for the sun and rain to clean them. If this was the case, the stones being reused as ballast would not have been the same stones taken from the same ship; they would have been stones taken from a ship which had stopped at the port at some indeterminate time in the past. The cleaning methods described here are somewhat conjectural as none of the documents encountered in the research for this thesis address whether or not, or by what process, stones would be cleaned or treated before entering, leaving, or being used in a terrestrial context.

Not all uses for discarded ballast would necessarily require fouled stones to be cleaned. The use of newly discarded stone as fill material to expand the shore or build roads, as was done on the Pensacola waterfront, would not be affected by dirty, foul smelling stones (Bense 1989[1]:63-70; Kennedy 2002: 232; McLellan 1944:12-13). Using fouled stones as ballast or in other structures, such as the Pensacola Hospital, the Fort at San Juan de Ulua, or the House of Cortez, could result in somewhat unpleasant living conditions if any food waste, animal remains, or human and animal excrement has become imbedded in cracks or holes in the stones. As the
next section will demonstrate, other properties of discarded ballast were also taken into account when determining the context in which particular stones were used.

**Ballast and Stone in a Terrestrial Context**

This chapter has described some general characteristics which made certain materials and stones desirable for use as ballast as well as some basic interactions between ships and merchants, however, other factors, such as the potential desirability of certain stones and interactions between neighboring merchants, must also be considered when discussing the transition of stone into, through, and from a terrestrial context. Aboard a ship, the main characteristic which determines how a stone is used appears to be its size, although other characteristics, such as roundedness, may influence where it is placed aboard the vessel. On land, the size of a stone may be considered but the type and composition may be more important as they can make a stone more suited for a particular purpose. In many cases, stone removed from ships was used for the same reason that crews chose many sources; discarded ballast was a convenient source of building material, regardless of its composition. This latter type of use is demonstrated in studies of structures in port-side cities.

One such study was carried out on a wall in King’s Lynn, Norfolk in the United Kingdom (Hoare et al. 2002). The wall was most likely constructed around the mid-thirteenth century and served as a defensive structure for the military as well as a means of controlling and taxing incoming goods and people (Hoare et al. 2002:91). Approximately ninety-five percent of the wall is constructed of various materials including bricks, slag, rubble, ashlar (rectangular stone blocks), concrete, and rocks of various sizes. Most of these materials are locally available, however some were introduced more recently when they were transported into the area and used to repair or rebuild portions of the wall (Hoare et al. 2002:96). The remaining five percent
consists of re-used ballast cobbles which include a variety of rock types. After cleaning and examining the visible surfaces of the stones, while leaving them in situ, the researchers noted a variety of rock types, many of which indicate a source in the northeast Baltic Sea. Other stones may be from areas in England and Scotland which were known to trade with King’s Lynn.

The use of ballast in this wall represents what appears to be a relatively straightforward movement of stone from a maritime to terrestrial setting. The earlier examples of ballast use on the Pensacola Waterfront, in particular those involving the sale of stone for fill or road construction, may have involved a similar, direct use of former ballast stone for the sake of convenience. The following examples demonstrate other factors and, potentially, other practices which could have influenced and complicated the manner in which stone entered a terrestrial context.

A study carried out in the cities of Brouage and La Rochelle, which are located on the west coast of France, revealed that while many structures, including previous examples in this chapter, were constructed of stones with no apparent reason behind their selection, certain medieval structures contained former ballast stones which were more suited for use in the context in which they were found (Lazareth and Mercier 1999). As with other studies, the researchers identified the stones as ballast because they were not native to the study areas. Lazareth and Mercier (1999) were able to connect some of the ballast from the structures they studied to Norway, Falmouth of Cornwall, UK, and the British Caledonides of Northern Ireland. The structures studied Brouage and La Rochelle included walls, foundations, and the remains of a coin manufacturer.

When studying the coin manufacturer in Brouage, France, built ca. 1400 A.D., Lazareth and Mercier (1999:125) noted that except for the furnace, what remained of the structure was
built of locally available Jurassic limestone. The interior walls of the furnace were built almost entirely of granite boulders which are not present in the local geology and were most likely imported as ballast. The granites were used for the furnace because of their higher refractory (heat-resistance) qualities. The researchers also recorded the presence of granites in the chimney of a medieval tower in La Rochelle which were presumably used for the same reason. The use of specific types of stone extends to other, less specialized structures, and possibly for different reasons.

Other structures which Lazareth and Mercier (1999) examined did not show the same specialization, however, they may reveal some interesting practices associated with the movement of ballast stone into a terrestrial context. For example, various sections of walls in Brouage are constructed of a single rock type; even between separate portions of the same wall there is no mixing of rock types. The authors explain the distinct sections of the walls and the lack of mixed rock types in other sites with two practices: direct transportation of ballast from the port of origin to the destination and immediate usage of the ballast for construction upon being discharged (Lazareth and Mercier 1999:127). Had the ships stopped for trade along their route to Brouage or La Rochelle, or had the ballast been left at the harbor for an extended period, it would have been mixed with stones from other sources. Taking stone directly from the ships also prevented it from mixing with other stone types at ballast dumping sites in the port (Lazareth and Mercier 1999:124). This same explanation is given for the single apparent source of the ballast stones used in the wall in King’s Lynn (Hoare et al. 2002:104). There may be other reasons for the degree of sorting which are not mentioned by Lazareth and Mercier and other authors.
If merchants or captains were aware of the potential appeal of different types of stone, either party could have sorted the stones to make it easier to access each type or purchased stones which they knew to be desirable. This type of sorting could occur both before and after the stones were used as ballast. The lack of mixing in the structures may be an indicator that the stone was intentionally shipped as a cargo of unmixed stone from a single source. Depending on the amount of stone used during the various stages of construction, each unmixed rock type found in the walls may represent contracts with different captains and/or merchants which required multiple shipments of stone. If captains were stopping at various ports in between the source of the stone and the destination, the stone may have been treated as cargo and been kept aboard while ballast was removed. They may also represent a shift to different types of stone as supplies of a particular type, which may have been built up by years of trade, were exhausted. The idea that merchants were sorting stone during the sixteenth century is hypothetical, however, it seems logical when examining the various situations in which a specific type of stone may be necessary or aesthetically pleasing and is not without a modern equivalent.

Modern stone suppliers, which often have a name including “sand and gravel,” are easily observable during a drive through many rural and suburban areas. Their properties can include anything from simple piles of stone sorted into various grain sizes to cinderblock cubicles filled with the same. The purpose of this sorting is to make each type easily accessible to any who may need it; mixing the different sized stones would only produce an unmanageable mess, especially when dealing with stone on the scale of sand and gravel. It does not seem unreasonable to think that the very same concepts could have influenced the handling of stone in the past. Such an arrangement is at least partially supported by the structures studied by Lazareth and Mercier (1999) and the records of the Luna expedition (Yugoyen 1569).
As discussed earlier, the organizers of the expedition were paying to have stone for ballast carted and shipped into Veracruz over large distances (Yugoyen 1569). This shows that merchants were not limited to selling stone to those in their immediate vicinity. It also reveals where the fleet was getting ballast, but does nothing to explain where the merchants who sold the stone acquired their supply. The merchants may have gathered the stone from somewhere in their vicinity or bought it from ship captains and other merchants in adjacent settlements. Merchants trading in stone may have been at work in Brouage and La Rochelle, just as they were in Veracruz. If those same merchants were sorting ballast, the resulting structures might display the exact characteristics which Lazareth and Mercier (1999) recorded in France.

The use of ballast, coral, or materials from other potentially sporadic or inadequate sources may have been disguised to some degree by intentionally mixing the various types of stone during construction. The result might be similar to the conglomeration of building materials visible in the King’s Lynn wall, the House of Cortez and the Fort at San Juan de Ulua (Figures 3-5). Such a configuration might have been more aesthetically pleasing than building distinct sections of a structure using different rock types.

Another feature of stone which would have influenced its role in any context is its durability. Before ever being touched by humans, a stone may have been sitting on the surface, exposed to the elements, for millions of years. In all that time, a stone may only undergo minor changes in shape as a result of weathering and erosion. A single stone may also slowly break down into smaller pieces, each of which would have nearly the exact same properties as the parent material. The same principles are true for stone after it has been collected for use by humans.
In a terrestrial context, if a stone is not immediately used, it may sit for anywhere from a few days to thousands of years after being collected. If the stone is not made inaccessible, either intentionally, accidentally, or through natural processes, it may remain relatively unchanged throughout the period during which it is in the possession of humans. Should the stone be used for any purpose, it may be modified to some degree in order to make it better suit the desired use. As long as that use does not involve exposure to extreme heat or chemicals, the stone will most likely retain its original characteristics.

Putting the same stone in a maritime context would most likely have the same lack of effect on the basic properties of the stone. A ship may not remain functional or retain any of its ballast long enough for the stones to show any visible changes, no matter what they are subjected to over the life of the ship. As long as the stone does not end up at the bottom of a body of water, it may be reused at the location at which it is unloaded. If, for whatever reason, a stone is broken while in use in either context, it would not necessarily be discarded. Instead, what remain are two or more stones which function in exactly the same way as the stone from which they originated. They may no longer fit the specifications of the use for which they were intended before breaking but they are not useless in all other contexts. If the fragments are repurposed, each of them may be carried along very different paths from that point on as they are used and reused over an indeterminate amount of time.

What These Practices Mean

By this point, it should be apparent that the processes by which stone entered, functioned within, and left the possession of humans were potentially far more complicated than those alluded to in previous ballast studies. How these practices may have affected ships prior to them becoming archaeological sites and the correlation between the practices and features within the
remains of a ballast pile will be addressed in Chapter V. The next two chapters outline the field and lab methods used in the course of this research (Chapter III) and the data resulting from the various analyses (Chapter IV). Chapter V then relates the results to the practices discussed in this chapter and outlines their archaeological implications.
CHAPTER III
FIELD AND LAB METHODS

This chapter outlines the various methods used over the course of the research for this thesis. The chapter begins with the basic reasoning and methods behind the collection of samples in the field. This is followed by a description of the process by which the stones were categorized by type and four stones were chosen for analysis. The chapter then discusses the analyses used to characterize the four stones and how the results of the analyses are used to determine the original sources of the stones. The chapter concludes with a brief description of the approach used to identify and determine the source environment of the coral recovered from EPI and EPII.

Field Methods

In order to address the research question, “what can be learned from stone ballast?” and to potentially identify features within the ballast pile, the field work portion of this research was focused on gathering ballast in such a way as to preserve as much information as possible. There were limitations on the scope to which UWF maritime archaeologists could gather data; the primary restrictions being time and working conditions. All ballast was gathered during field schools by students and the supervisors training them in the methods of maritime archaeology. The working conditions for the divers on EPII varied, but for a majority of the time, nearly all excavation and collection was done in close to zero visibility. These conditions restricted the precision with which the provenience of the ballast could be recorded.

With these limitations in mind, a single unit, 91N 492E, was excavated specifically for this thesis. In order to ensure that the spatial distribution of the ballast could be studied, ballast was primarily taken from a single 1 m by 1 m unit in a previously undisturbed area of the ballast pile in the amidships of EPII. Each quadrant of the unit was excavated individually, in 20 cm
levels. All ballast in the unit was gathered into milk crates and buckets on site before being lifted to the barge, taken to UWF archaeology collections facilities, and stored separately based on the quadrant and level from which it was collected. Large stones which crossed between two or more levels were collected independently and all location information was recorded. The entire unit was excavated to 100 cm with the NW quad extending to 120 cm.

Before the unit could be excavated completely through the ballast pile to the underlying hull, the walls of the unit, which consisted of loose stone, sand, and mud, began to lose stability and collapse. As a result, excavation through the 80 cm to 100 cm and 100 cm to 120 cm levels generally began with the removal of loose material which had collapsed from the walls between periods of excavation in the unit. Landscaping cloth and sandbags were placed on the bottom of the unit between periods of excavation and left over the quadrants which were not currently being excavated. The cloth made it possible to remove collapsed material without disturbing the unexcavated ballast below the cloth.

Laboratory Methods

Rock type identification

The first step in processing the ballast was to identify the various rock types within the recovered materials and the distribution of the types throughout the levels of the unit. This involved going through the ballast piece by piece and identifying each stone based on characteristics visible with the naked eye or through a 10x magnification loupe. The characteristics used to identify each rock type included grain size and shape, general composition, color, foliation, etc. (Davidson et al. 2002; Fry 1984; Thorpe and Brown 1985; Tucker 2003). Dr. Matthew Schwartz of UWF and Dr. Jon Bryan of Northwest Florida State
College assisted with rock type identification. The only rocks which required an additional test to confirm their identity were those composed of calcium carbonate (CaCO₃).

Calcium carbonate rocks, the only present type being limestone, were identified by their reaction to hydrochloric acid (HCl) diluted with water to a 5% solution. An eye dropper was used to place a small drop of the diluted acid on one or more clean areas of the rock. A chemical reaction, visible as bubbles within the acid solution on the surface of the stone, signified the presence of calcium carbonate; rocks which do not contain this compound show no reaction to the acid. Except for the stones which were obviously not composed of calcium carbonate, such as basalt, all stones were tested with the acid. Calcium carbonate rocks were classified as limestone unless they had visible features consistent with coral, such as the corallites.

**Geologic Analyses**

Four ballast stones were chosen from EPI and EPII for further analysis; three from EPII and one from EPI. The three from EPII were chosen primarily because the locations from which they were collected, including X, Y, and Z coordinates, were recorded and each comes from a different depth. The stones are also sufficiently large so as to provide enough unaltered core material for the analyses outlined in the next section. The vertical distribution of the samples potentially adds a time aspect to this study which was not present in the study by Wohlberg and Kelson (2009). Depending on the results of the analyses, these stones may show a change in ballast sources over time. The fourth sample, from EPI, is one of the only basalt ballast stones collected from the site. Even though its provenience was not recorded, it can reveal important information about EPI just as the sample used by Wohlberg and Kelson (2009) hinted at EPII’s unknown history. For the remainder of the thesis, the individual samples are referred to by the artifact numbers assigned to them in the lab. The sample from EPI is 94-97L. The samples from
EPIII are 10W2883-001, 11W3440-001, and 11W3447-001, but will be referred to without the “-001” for the sake of readability.

To prepare the samples for analysis, fresh, unaltered material had to be cut from the core of each stone. This was a relatively simple procedure performed with a tile saw. A large portion of each stone was removed with the tile saw and the outer, altered rock, called the rind, was cut away (Rapp 2009:260). What remained was the core which was unaltered by outside forces and would provide the most reliable information as to the original composition of the stones. The core of each sample was then cut into large pieces which were sent to three labs for analysis.

The four samples have each undergone three different analyses: thin-section, whole rock geochemical analysis and Argon-Argon (Ar-Ar) dating; each analysis provided different types of information about the samples. Making thin-sections allows for an examination of the crystal structure, the general composition of a sample, and the integrity of the sample (i.e. lack of alteration). The whole rock geochemical analysis results in a specific measurement of the composition which shows the presence and amount of a large suite of elements present in the sample. The Ar-Ar analysis completes the set by giving an age range for the sample.

The purpose of making thin-sections, completed by Wagner Petrographic, was to create a paper-thin slice of each stone in order to get a clearer look at the crystal structure and the composition in order to verify the unaltered state of the core material. A piece measuring approximately one by one by two inches was cut from each sample and sent to Wagner to be processed. To cut a thin-section from each of these pieces, one side was flattened and polished then epoxied to a glass slide (Peterson 2009). The excess was then cut away from the glass and what remained was ground down and polished until it was approximately 0.030 millimeters thick.
The whole rock geochemical analysis, conducted by ALS Minerals, was used to determine the composition of the samples. The analysis involves applying multiple techniques to the samples in order to detect different elements, including rare earth elements and gold, which can be used to determine the tectonic environments in which the rocks formed as well as compare the samples to any potential sources (Rollinson 1993). The two main techniques used to determine the composition were inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectroscopy. Both techniques involved dissolving the samples in solution then injecting the solution into an inductively coupled plasma torch (Becker 2007). The plasma torch vaporizes and ionizes the particles within the solution before they are introduced into the next stage in the process.

Once the particles are ionized, they are transferred into one of two systems: the mass spectrometer (MS) or the atomic emission spectrophotometer, also known as an optical emission spectrophotometer. The MS works on the principle that ionized particles of different elements will have unique mass to charge ratios and can be separated and measured (Becker 2007). As the ions are fed into a mass analyzer within the MS, they travel different distances along the detectors and strike the detector at a location determined by their mass to charge ratio. This contact is measured and used to determine the ratios of different elements. The atomic emission spectrophotometer works on the principle that when the ions are heated to the appropriate temperature, each element will emit a distinct, measurable electromagnetic radiation in amounts relative to the amount of that element in the sample. The precise measurements resulting from these techniques are most useful when used in conjunction with the third analysis.

Argon-Argon (Ar-Ar) dating, performed by the New Mexico Geochronology Research Laboratory, is a variation on Potassium-Argon (K-Ar) dating; both rely on the principle that
Potassium ($^{39}\text{K}$) decays into Argon ($^{40}\text{Ar}$) at a known, measurable rate (McDougall and Harrison 1999; Heizler 2013). In order to perform Ar-Ar dating, the samples are irradiated in a nuclear reactor along with a sample of known age. The irradiation converts the $^{39}\text{K}$ in the samples into $^{39}\text{Ar}$. The ratio of the $^{39}\text{Ar}$ to $^{40}\text{Ar}$ is then measured in the samples and compared to the sample of known age which is used to determine the rate of conversion and calibrate the analysis for the samples of unknown age. The age of the unknown samples can then be measured relative to the age of the known sample. The exact methods and instruments used for the dating are included in the geochronology lab report in Appendix A.

*Stone Ballast Sourcing Methods*

When the analyses were complete, the information was compared to geologic literature and potential sources were identified. The information from the geochemical analysis and Ar-Ar dating were particularly useful for this stage. Through the use of total alkali versus silica and discrimination diagrams, the ratios of certain compounds found within the samples were compared in order to reveal the specific type classification of each stone and the tectonic environment in which the sample formed. Once the source environment for a stone was identified, this information was used in conjunction with the age determined through Ar-Ar dating to locate literature pertaining to rocks of the correct age and type. As of yet, there is no central database of the earth’s rock outcroppings, however, geologists have collected and analyzed samples from around the world and published their results. A thorough literature search, the results of which are discussed in the next chapter, has revealed some potential sources around the Atlantic Ocean.
Coral Identification and Sourcing

In addition to sourcing four of the stones, images of coral samples from EPI and EPII were examined by specialists at the office of the Environmental Protection Agency in Pensacola, Florida and the Mote Marine Laboratory and Aquarium in Sarasota, Florida. They were able to identify the presence of a few different species of coral. The habitats and ranges of the different species are examined in order to determine the potential area from which the coral may have been collected, as well as evaluate the usefulness of studying coral recovered archaeologically.
CHAPTER IV

RESULTS

The purpose of this chapter is to outline the results of the analyses described in the previous chapter. The data is closely examined in this chapter to more specifically classify the four basalt samples. This examination includes charting various compounds found within the stones and comparing the resulting classifications to the measured ages of each stone. Though the geologic analyses were limited to a few samples, the data have proven useful in determining possible sources for the stones. The chapter ends with a brief outline of the identified coral species and their origins.

Rock Type Distribution

Within the excavated unit, there were a few general rock types which appear throughout the 1025 recovered stones, weighing 1174.6 kilograms (Figure 6; Appendix B). Approximately 63.3% by weight of the recovered material was basalt identical in appearance to the three samples from EPII which were analyzed. Basalt comprised a majority of the boulders within the ballast as well as much of the smaller material. The only other boulder of note was a single boulder-sized piece of granulite which came from the 40-60 cm level of the unit and measures 45 cm across at its widest. As will be discussed later, the granulite may be significant because of its potential association with the basalt from EPI. The other types within the unit were granite, chert, sandstone, limestone, quartzite, soapstone, phyllite, serpentine, slate, shale, and coral. All of these types included stones ranging in size from large pebbles to large cobbles with the occasional small boulder and most were found in every level of the unit. The less common stones including granulite, serpentine, phyllite, shale, soapstone, sandstone, and slate were neither present in all levels nor in large concentrations in a single area.
Figure 6. The ballast stones recovered from EPII. Photograph by author.
Approximately 13% by weight of the recovered ballast stone was classified as indeterminate and had eroded to the point that identifying and counting it was not possible. The material was very friable, meaning it crumbled easily (Tucker 2003:78). Most of this material appears to be basalt and may be similar to the stone shown in Figure 7 which is unstable but has not completely lost its integrity. It was not uncommon for stones to crumble as they were being excavated. An unknown amount of this material could have completely fallen apart and been dredged up. Some stones were recovered from the dredge spoil but others may have passed through the netting and screens with the sand.

Geologic Analyses

Thin Sections

The primary purpose of the thin sections (Appendix C) was to verify that the cores of the four ballast samples recovered from EPI and EPII were unaltered and would therefore be more likely to match the composition of their source. Taking thin sections prior to performing further tests also ensured that the stones were not weathered and degraded like the indeterminate material described in the previous section. The four thin sections display neither discoloration, like the stones’ altered rinds which were visible as a lighter region around the edges of cut stones, nor deformation of grains (e.g. stretching or bending) which would be expected if the stones had been subjected to high degrees of heat and/or pressure in a metamorphic environment (Davidson et al. 2002:107-115).

Geochemical Analysis

Major and trace element data from whole rock geochemical analysis (Appendix D) were used to verify the exact rock type based on the ratio of alkalis ($K_2O + Na_2O$) to silica ($SiO_2$) (Figure 8) (Le Bas et al. 1986). Sample 10W2883 is a basaltic trachyandesite; the other three
Figure 7. Basalt which is heavily altered and no longer stable. Cracks are visible across its surface and the stone is easily reduced to sand-sized grains by hand. Photograph by author.
Figure 8. Total alkali versus silica diagram used to classify igneous rocks. Original diagram described in Le Bas et al. (1986). Data from potential sources is included for comparison. Lanzarote and Canary Islands data is from Carracedo et al. (2002:464). Salvador basalt dike data is from Iacumin et al. (2003:368).
samples are basalts. The additional use of Figure 8 as a means of comparing the samples to potential sources is addressed in section 4.3. Applying the geochemical data to other types of diagrams aids in determining the tectonic environment in which the samples formed.

Three different discrimination diagrams were used to determine possible tectonic environments in which the samples formed to aid in narrowing down potential sources (Figure 9a-c). When applied to the Hf/3-Th-Ta diagram (Figure 9a), all four samples are shown to have formed at a destructive plate boundary (Wood et al. 1980:12). Basalts from this type of plate margin are found in island arcs which form when magma wells up from the mantle, erupts, and cools at or on the surface. More specifically, based on the position of the data points in the lower portion of section D, the samples are all calc-alkaline basalts.

In Figure 9b, the samples fall into two categories. Samples 94-97L and 11W3440 are in section C and are classified as volcanic arc basalts; samples 10W2883 and 11W3447 are in section AI and are classified as within-plate alkali basalts (Meschede 1986:210-211). In the diagram, section C appears to be separate, yet it is actually a somewhat ambiguous area between basalts formed at mid ocean ridges (section D) and those which extruded through oceanic or continental plates (section AII). When plotted into Figure 9c, sample 11W3440 is categorized as an island arc tholeiite; the other three samples are ocean island alkaline basalts (Xia et al. 2003:320). Although there is some variation in the classifications indicated by the figures, they all point to a similar environment and formed in the same manner as identified by Figure 9a (Thorpe and Brown 1985:1-4).
Figure 9. Discrimination diagrams used to determine tectonic source environments of the four analyzed samples. (a) Hf/3-Th-Ta diagram found in Wood (1980). A: N-type mid-ocean ridge basalts (MORB); B: E-type MORB; C: alkaline within-plate basalts; D: destructive plate-margin basalts. (b) Nb*2-Zr/4-Y diagram found in Meschede (1986). A1 and AII include within-plate alkali basalts; AII and C include within-plate tholeiites; B includes plume- or enriched-type MORB; D includes normal-type MORB; C and D also include volcanic arc basalts. (c) TiO$_2$-MnO*10-P$_2$O$_5$*10 diagram found in Xia et al. (2003). OIT: ocean island tholeiites; MORB: mid-ocean ridge basalts; IAT: island arc tholeiites; OIA: ocean island alkaline basalts; CAB: calc-alkaline basalts.
Argon-Argon Geochronology

Argon-argon (Ar-Ar) geochronology data (Appendix A) places the samples into distinct ages. The stones from EPII, 10W2883, 11W3440, and 11W3447, formed during the Late Miocene and are 7.183 ± 0.052, 7.113 ± 0.048, and 7.429 ± 0.028 million years old, respectively (Heizler 2013). The overlap in the errors on samples 10W2883 and 11W3440 mean they are statistically the same age. The stone from EPI, 94-97L, formed during the Middle Proterozoic and is 1040.9 ± 1.5 million years old.

4.3 The Combined Geologic Data

When the characteristics revealed by the geologic analyses and the diagrams are combined, the potential sources of the stones can be narrowed down to two distinct locations. Basalts from the late Miocene, which are similar in composition to samples 10W2883, 11W3440, and 11W3447, can be found on Lanzarote, one of the Canary Islands. Middle Proterozoic basalt dikes similar in composition to 94-97L are found on the coast of Brazil, near Salvador.

Comparing the geochemical data to the range of samples in Carracedo et al. (2002:464) (Figure 8) shows that 11W3440 and 11W3447 fall within the range of recorded compositions from Lanzarote; sample 10W2883 falls outside the main cluster of basalts on Lanzarote but is within the range of outliers on the diagram. Further research into Lanzarote’s geology may eventually fill in the gaps in the data. The samples from EPII also fall within the range of samples from other islands, but only the basalts on Lanzarote match the ages of the samples. More specifically, the Los Ajaches volcano was the only active volcano during the period in which the samples from EPII formed (Acosta et al. 2003; Carracedo et al. 2002; Hoernle and
Carracedo 2009). The other volcanos of the Canary Islands were all dormant, including the Famara volcano which is also located on Lanzarote.

When the location of sample 94-97L on Figure 8 is compared to the data from Iacumin et al. (2003:368), the sample is similar in composition to dikes near Salvador. Additionally, the ages of some of the dikes overlap with the Ar-Ar age of sample 94-97L and many others are close in age (D’Agrella-Filho et al. 2004; Renne et al. 1990). The reasons for variation in the compositions in all the samples, even those from the same source, are discussed in section 5.4.1.

**Coral Identification and Origins**

Using images sent to them, the specialists at the EPA (Jed Campbell) and Mote Marine Laboratory (Eugene Shinn) were able to identify some of the coral taken from the EPI and EPII. Four different types were identified, all of which are found in the Caribbean. These are *Oculina, Siderastrea siderea, Montastraea annularis,* and *Diploria* (Jed Campbell, personal communication 2012; Eugene Shinn, personal communication 2012). Each of these species has a specific habitat within which they can grow. For example, *Siderastrea siderea* (massive starlet coral) can grow in shallows or at depths of up to twenty meters and may share much of that habitat with *Montastraea annularis* (lobed star coral) (Warner 2012:65-67, 108-109). The various species of the genus *Diploria* (brain corals) can survive in depths ranging from one to thirty meters (Warner 2012:116-120). The habitat of *Oculina* (ivory coral) is only slightly more limited as it requires a protected area between one and eleven meters deep (Warner 2012:54-56). Although the individual species can have a relatively small ecological niche, as a result of the process by which coral reproduces, they may thrive nearly anywhere in and around the Caribbean in which that niche exists as long as other conditions are met including temperature, available light, salinity, nutrients, and sediment (Spalding et al. 2001:16, 22). The types of
conclusions which can be reached based on the presence of coral, and other types of ballast, are discussed in the next chapter.
CHAPTER V
TOWARD A THEORY OF BALLAST

The purpose of this chapter is to describe what can be learned from ballast through archaeological investigations. This is accomplished by first examining the relationship between the results of the previous chapter with the histories of the ships. The majority of the chapter then focuses on the archaeological effects of the practices which comprised Chapter II. This chapter then ends with the conclusions which can ultimately be reached about ballast from EPI, EPII, and shipwrecks in general when the practices and other factors are taken into account.

Evidence vs. History

Historically, the sources pointed to in the previous chapter fit within what is known about the extent of maritime exploratory activities during the sixteenth century; however, Brazil and the Canary Islands were known to have been visited in the decades prior to the expedition, but they do not necessarily fit into the histories of EPI and EPII. Currently, almost nothing is known about the history of the ships beyond what is outlined in Chapter I. The available information about their histories does not include any references to the ships visiting the locations pointed to by their ballast. Rather than being present as a result of the movements of these particular ships, the stones may, in fact, have come to reside on the ships as a consequence of the practices outlined in Chapter II.

Of the two sources, the Canary Islands were most likely visited by the Spanish; the islands were the first and last place ships could stop before and after the long voyage across the Atlantic Ocean (Lamb 1988:64). Two of the studies mentioned in Chapter I also show connections to the Canary Islands. The ballast study of EPII by Wohlberg and Kelson (2009) indicated a connection to Gran Canaria. Ballast from the Molasses Reef Wreck (MRW) also
matches the age and type of basalts found on Lanzarote (Lamb 1988:71). Adding samples 10W2883, 11W34440, and 11W3447 to this list reinforces and refines other evidence of a connection to the islands.

The sample from EPI, 94-97L, appears to be from the coast of Brazil, but has a more tentative connection to its source than the sample from EPII. Depending on EPI’s connection to the stone, it may support the idea that the contemporary activities of all nations must be considered when studying ballast. Brazil was officially discovered by the Portuguese explorer Pedro Alvares Cabral in 1500 (Burns 1993:495). In 1549, Salvador was founded on the shore of All Saints’ Bay (Baía de Todos os Santos) as the capitol of Brazil (Russell-Wood 1989:62, 64). At the time, it was one of the first commercially and strategically important Portuguese settlements in Brazil (Burns 1993:48).

The basalt dikes from which sample 94-97L appears to have originated are located along the southeast shore of the peninsula on which Salvador was established with patches of dikes extending inland to the northeast (Moraes-Brito et al. 1989:11) Initially, stone may have only been collected from sources near the shore, but as the area was settled, other inland sources would have become more accessible and could have been carried to locations from which ballast was taken. The use of inland sources may not have occurred until long after the Luna expedition, but that does not mean that ballast from inland areas was not carried to the shoreline by natural forces. Additionally, granulites formed in the same area and were later penetrated by the dikes; future research may connect the granulites found on EPII to this region, thereby supporting evidence of a connection (D’Agrella-Filho et al. 2004:57; Iacumin et al. 2003:370; Moraes-Brito et al. 1989:9).
While it is entirely possible that Spanish ships visited the area at some time before the expedition, they would not have to in order to end up with ballast from the area in their hold. If even a single ship, of any country, stopped in the area to resupply and/or take on ballast before stopping in a Spanish port to trade and acquire fresh ballast, stone from the area could have been introduced into the maritime economy of the Caribbean and Spain. The same is true of the samples from the Canary Islands; however, the fact that so much of the ballast recovered form EP II consists of basalt, the sample from the upper level matches those below, and Spanish ships are known to have stopped there, it seems likely that the ship actually visited the islands. The other explanation is that large amounts of basalt were transported from the Canary Islands, discarded in New World ports, and used to reballast the ship at some point prior to the expedition. The extent to which such interactions may occur and their effects on the archaeology of ballast are addressed in the next few sections.

Archaeological Effects of Practices

The purpose of this section is to expand on the descriptions which comprise Chapter II by outlining some of the potential archaeological impacts of the practices. To a large extent the practices may seem to only be relevant in direct reference to the ship, which makes it easy to imagine them as functioning aboard a vessel which operates separately from the rest of its contemporary maritime context. For much of a ship’s life, this may be true. While a ship is not at port, it functions as a more or less autonomous unit aboard which the crew performs the necessary tasks which can include the discarding, collecting, and loading of ballast. If we only consider these practices, the role of ballast appears to be relatively straightforward and the practices could leave distinguishable archaeological signatures; however, as the remainder of this
section will illustrate, even the relatively simple practices can be heavily influenced by the wider context in which the ship exists and functions.

**Ballast Materials**

As mentioned in section 2.1, multiple material types may appear among the ballast of a shipwreck regardless of the predominantly used materials of the time. For example, although pig iron and other forms of metal were not used as a primary form of ballast until the eighteenth century, metal may be found among stone ballast. During the 2009 UWF Maritime Field School, which included excavations on EPII, a single large piece of pig iron was recovered from the center of the ballast pile where it was buried under multiple feet of loose stone. At some point when the level of ballast was lower or while ballast was being loaded, the piece of iron could have been dropped into the hold and left among the ballast. If adding the iron to the ballast was intentional, it may have been ballast for an indeterminate amount of time before the expedition. However, it is entirely possible that the iron was accessible while the ship was underway and only became buried in the ballast when the ship was battered by the hurricane. Materials may also be added to the ballast pile of a ship long after it has wrecked.

Depending on the amount of energy in the environment surrounding a site, the presence of certain grain sizes, including gravel, sand, or anything smaller, may be obscured by the sediments found at and around the site of the shipwreck. In environments with periods of very high-energy as a result of flooding or storms, regardless of their length, it may even be possible for larger grained materials such as cobbles or boulders to be introduced to the site. The extent to which any given shipwreck is affected by these forces will depend on the location of the wreck; some shipwrecks may remain almost completely intact while others are slowly stripped of nearly everything before new sediment, possibly containing modern or unrelated materials, is deposited.
on top of the site. To a large extent, EPI and II were protected by the sediment and marine life in the bay. Both sites have undoubtedly been penetrated by the sediments found in Pensacola Bay, but the presence of small, fragile items including plant and animal remains, as well as small wooden artifacts such as beads and a spoon, attest to the degree to which the artifacts and original ballast have been preserved. Other wrecks are not as protected and may have both artifacts and stone introduced by outside sources. The potential for the introduction of extraneous materials is discussed in detail in section 5.4.

Careening and Cleaning the Hold

Although the procedures leading into cleaning and careening can be different, their ultimate effect on the features of ballast could be identical. In their limited forms, these practices could involve moving ballast in slightly different ways as the crew gains access to different features of the ship. For example, a parliamentary heel, described in section 2.4, may not involve the disturbance of all the ballast in the hold; it may be only the topmost, immediately accessible portion that is shifted from side to side while leaving the lowest portions of ballast in place. In much the same way, moving a small amount of ballast away from a specific area of the hold in order to clean would not necessarily require ballast in other areas to be moved. In these cases, only a portion of the potential archaeological information could be lost; however, when these practices are carried out to their fullest extent, all ballast could be moved and/or removed, thereby destroying any features within the ballast. When a ship was fully careened, cleaning the hold may have been carried out at the same time. The opposite is not necessarily true; a hold could have been cleaned to prepare it for cargo without going so far as careening the vessel. If any portion of the ballast is replaced with material other than that which was removed, evidence of connections to previously visited ports could be lost.
If the debris found at the bottom of the hold of EPII during excavations is even a slight indication as to the potential volatility of the environment below-decks, the hold would have been, as many archaeologists and historians have acknowledged, an extremely unpleasant place to work. During field operations conducted as part of the 2009 UWF Maritime Field School, the stern of EPII was exposed and excavated. As with all material recovered from the site, UWF archaeologists screened and sorted through the dredge spoil from the stern. An immediately noticeable feature of the spoil from the deepest sections of the ship was a pungent smell akin to sewage. Within this dredge material were hundreds of cockroach wings as well as the remains of other small insects and rodents (Shidner 2011:89). While it is possible that the aroma resulted from materials which were introduced long after the ship wrecked, material recovered from other areas of the wreck did not share the same smell.

If it turns out that the ships were careened and/or cleaned before the expedition and the condition of the dredge spoil is an indication, it may not take long for refuse to build up. For EPII, the period during which the ballast may have become fouled could include some time, as far back as January 24, 1559 when the ship was leased for the voyage from Veracruz to Pensacola which lasted from June 11 to August 15, 1559, and the month between reaching Pensacola Bay and the arrival of the hurricane (Worth 2009). The period for EPI would be much the same except that it was purchased more recently (February 22, 1559). That gives both ships up to seven to eight months during which material could build up after being careened for the expedition. As of yet, there are no known records which describe the ships of the fleet careening while in Veracruz, and because so little is known about the history of the ships, they could have been careened days or years before joining Luna’s expedition.
The idea of permanent ballast is thoroughly discussed in section 2.2.1 where it is argued to be an inaccurately applied term when referring to stone ballast. To illustrate why, the reasons for tasks like those described in the section above can be applied to the stones themselves. For example, when removing ballast from the hold for the purposes of cleaning or careening, everything could be removed and an indeterminate amount of ballast could be replaced with fresh material. Particular attention would probably be paid to the stones at the bottom of the hold which may be classified as permanent ballast; these would be covered in all the filth that filtered from above and may have been discarded sooner than overlying, potentially cleaner stones.

Other reasons for the potential inapplicability of this term include the transportation of adequately heavy cargo with little to no ballast left on the ship, as seen on the Yassi Ada wreck (Bass and Doornick 1982:63-64) and the potential for the stone to be included among the wares to be offloaded and sold, as discussed in sections 2.2.2 and 5.2.5.

If what maritime archaeologists have referred to as permanent ballast was truly indistinguishable from other stones, describing larger stones as permanent ballast may misrepresent their actual, and immeasurable, duration of use. The actual period of use may be no different than that of smaller stones. If a distinction must be made, a reference to position may be more applicable than a classification by size. The term “mobile ballast”, which could also be referred to as “shifting ballast,” may be applied to the upper, accessible portion of the ballast (Lamb 1988:6; McEwen and Lewis 1953:32). An adjective such as immobile, or a synonym thereof, may be used to classify the lower portion of the ballast pile which is neither accessible nor permanent. Any changes in the sizes of the stone may be evidence of intentional sorting and loading techniques. Placing larger stones at the bottom of the hold may have ensured that the
upper stones which would potentially have to be moved were small enough so as to be easily shifted and arranged around items in the hold. The features which may result from this type of loading, as well as an example of these features on a shipwreck, are discussed in-depth in section 5.3.

**Ballast Sources**

When it comes to identifying ballast sources, archaeologists may have to rely on a combination of logic and geochemical analyses; actual ballast collection sites may be difficult to identify if they have not been completely destroyed. To gain some insight into the qualities of a potential quarry site, it is useful to begin with an examination of the scoops at Hengistbury Head which are the earliest features identified as the likely result of ballast-quarrying. The location and features of the quarry portion of this site exemplify the very reasons why this spot was chosen as a source of stone and why sites like this are not often discovered by archaeologists (Taylor 1998; Cunliffe 1987). The gravel of the old shoreline would have been immediately available and easily loaded by the crews of the boats dropping off cargo; however, the same proximity to the landing site has resulted in the partial destruction of the quarry hollows. In some areas of the site deposition of sediments has expanded the shoreline, thereby preserving the original shoreline and archaeological features contained within; other areas have been eroded by the same forces. The fact that Hengistbury Head still contains any features may be at least partially attributed to the protectiveness of the surrounding geography for which the site was most likely originally chosen, and why it remained in use for thousands of years. Other locations which are not nearly as protected or which are located in entirely different environments may not survive or remain identifiable.
Certain sites, such as the bed or shore of a river or exposed beaches, may retain no traces of human action which could not also be caused through natural forces such as scouring, heavy currents, or increased wave action, which may occur during a storm or flood. In some cases the evidence of quarrying may simply be washed away by these forces. Other locations, such as any from which large stones are gathered, may not retain features fine-grained or clustered enough to be identified without a large-scale excavation. The degree of impact by the crew of a ship and/or any humans which inhabit an area could be just as influential in determining the survival of a site. The relatively small duration over which a single crew may remain at an otherwise uninhabited location may result in a small, fleeting impression on the landscape, whereas the actions of those living in long-inhabited locations, such as Veracruz or Pensacola, may involve continually modifying the shore and inland areas to fit their needs.

The range of potential sources which may be available to ships stopping at these general types of locations can also vary dramatically. A ship at a remote location may contain the supplies needed for a trek inland, but the crew may not use that opportunity to gather stones unless they are particularly rare and desirable. Instead, the crew may only gather ballast from the most accessible sites, i.e. those which are immediately adjacent to the water or only a short distance from the shore. If this is the case, it seems as if it would make it easier for archaeologists to identify a relatively small area in which all the types occur; however, any location, and the objects contained therein, may have a complex geologic history which involves a large portion of the surrounding landscape.

The area from which the stones at a particular location may have come could range in size from a series of outcrops, like the basalt dikes of Salvador, Brazil, to a portion of a drainage basin from which stones could have been carried by creeks, rivers, landslides, or a combination
of these and other natural forces. Depending of the size of a drainage basin rocks may eventually
be carried hundreds of miles from their original outcrop. Despite the potentially complex mixture
of rocks, careful examination of the rock types and the geography accessible to mariners and
local settlements may allow the probable collection area to be identified with some certainty
even if no other evidence is visible at the location.

Long-term sites like those mentioned have many more sources from which to gather
stone. Merchants and other stone gatherers can use the same types of local sources as mariners
yet, if they so desire, they can more easily gather any supplies which would be needed to explore
the surrounding area and gather stone they found inland. If it is an established port, and a
frequent stopping place for passing ships, any ballast discarded by those ships can be collected
and reintroduced to the economy. Additionally, they would be able to trade with nearby
settlements which could have both gathered stone in their vicinity and traded with other
settlements which are even more distant from the first.

An issue with any quarry site, whether it is located far inland or directly adjacent to the
water, is the uncertainty as to the stone’s intended purpose. For example, stone specifically
quarried for construction from an inland source may still end up as ballast if the need arises. This
may be what occurred in Veracruz when stone was shipped and carted to the port. The same
uncertainty applies to stone taken from a location which is close to a known landing site or port;
while it may predominantly be used as ballast, the other potential uses cannot be dismissed. This
is demonstrated by the use of ballast in structures. If the stones were not specifically shipped to
the area for use in construction, the discarded ballast may have been kept close to the shore with
the intention of loading it back onto a ship; portions of it could then be sold to local buyers if it
was not immediately needed by a ship. It is possible that any identifiable sites, including ballast
dumps and quarries, could have shifted in and out of use while the stones taken from them
remained in more or less continual circulation.

When it comes to actually identifying ballast sources utilized in a particular port, there
may be a few potential avenues of research. The first is documents, like the records of the Luna
expedition, which can be used to begin reconstructing the paths through which a stone may have
traveled from source to use. The second potential source of information is buildings within a
settlement. Portions of any type of stone which passed through the settlement may have been
repurposed for a construction project occurring at the time (Buckland and Sadler 1990; Lazareth
and Mercier 1999). The third source of information is the ships themselves, but not just any ship.
A ship which was built at a particular port and which sank shortly after launch could be the most
revealing. The Vasa, which sank only minutes into its voyage, is a prime example of this type of
situation (Franzén 1960; Ohrelius 1963). One of the ships which actually took part in Luna’s
expedition, the La Salvadora, may also reveal much about ballast sources if it is ever found.

Of the ships which were lost to the hurricane, the La Salvadora was the only one which
was built in Veracruz (Worth 2009). It was also one of the smallest ships in the fleet. As with all
the ships built in Veracruz, prior to setting out with Tristán de Luna, the La Salvadora would
more than likely not have been involved in any other voyages. If this was the case, and assuming
that no stops along the way involved emptying the hold, the ballast aboard the ship could include
much of the same ballast which was loaded when the ship was initially constructed and loaded
with material, including ballast and supplies. Small amounts of ballast could have been taken
away, added, or moved throughout the loading process, but since it never left Veracruz prior to
the expedition, nearly all ballast would have come from sources in and around Veracruz. This
does not mean the stones themselves came from the area, only that they were in the stockpiles which were used as ballast.

The Luna documents show that stone was transported over large distances specifically for use as ballast (Childers 1999; Yugoyen 1569). Depending on where the stones from various sources ended up, this may or may not be reflected in the ballast of La Salvadora. The situation in Veracruz may have been somewhat unique insofar as the amount of ballast needed to supply the ships. Needing to completely ballast three ships, and fully or partially reballast any number of the other eight, may be the reason so much ballast was bought for the expedition and transported in from other locations rather than being taken from local sources. Again, taking the stone from local sources does not mean the stone formed in the region, only that it was immediately available within the city.

Given that the La Salvadora was one of the smallest ships in the fleet, it may have been the ship which the hurricane threw inland (Worth 2009:89). If this wreck is located, on land or in the water, its contents could reveal a lot about where ballast was being collected in Veracruz. Unfortunately, this ship may never be found by archaeologists if it was thrown inland. The colonists are documented to have completely salvaged the remains of the ship in order to help them survive and attempt to build their new colony (Dávila Padilla 1955).

The other two ships which were constructed in Veracruz, the San Juan de Ulua and San Luís Aragón returned to Veracruz (Worth 2009:85). The San Juan de Ulua was the ship which returned to Veracruz upon the fleet’s arrival in Pensacola Bay and later participated in the effort to rescue the colonists stranded in Florida. When their business related to the expedition or rescue effort was concluded, these ships could have gone on to sail throughout the Spanish Empire, or beyond, loading and unloading people, cargo, and ballast wherever they traveled.
Ultimately, any ballast which was loaded in Veracruz would be partially or completely removed, and what remained could be mixed with ballast from many locations, thereby obscuring any evidence as to where ballast was collected in Veracruz.

The potential for the activities of a ship to obscure any evidence pertaining to the actual location at which a particular type of stone was loaded increases as more ports and ships join the network of maritime trade. Ships like the *La Salvadora* are important to ballast studies because they can supply at least a partial sampling of the types of stone used as ballast in a port at a certain time. Without carefully recorded, contemporary documents which specifically address stone or ballast, there may be no other way to get an accurate idea of the types of stone to expect on a shipwreck. Unfortunately, such documents most likely do not exist for something as trivial as stone except in specific cases where the ballast itself was also cargo.

*Ballast as Cargo*

The possible role of former and future ballast stones as a commodity in port cities and their neighbors adds a level of complexity to the movement of stone which has only been partially addressed. As section 2.2.2 showed, differentiating between ballast and cargo is not always straightforward. Everything acts as ballast and certain items which might normally be classified as cargo could remain aboard as ballast indefinitely or function as the primary form of ballast until they were unloaded. As the following examples will show, it may be just as difficult to accurately classify a material as ballast even if it is generally accepted as such.

Lazareth and Mercier (1999) offer valuable examples of the reuse of ballast within their discussion of former ballast stones found in various structures located in Brouage and La Rochelle, France. Their study, which is described in more detail in section 2.8, identified exotic stones which were introduced to the cities as ballast and then used in the construction of a
furnace as well as for walls, foundations, and other structures. The furnace is particularly interesting because the granite used to build it was apparently chosen specifically for that feature of the foundry (Lazareth and Mercier 1999:125). The other structures did not require a specific type of stone yet they showed an unusual degree of sorting; large sections of the walls were built with former ballast stones and did not include stones found locally (Lazareth and Mercier 1999:124). When these uses are considered in terms of their effect on the archaeological record, they bring to light some interesting possibilities.

Gathering granite for the furnace had two effects, one practical and one archaeological. In practical terms, the higher heat-resistance qualities of the granite made it better suited for use in a high-temperature environment (Lazareth and Mercier 1999:125). When considered archaeologically, the effect of gathering the granite appears simple, yet it may be more complex and far-reaching than it seems. The occasional need to collect stones of a particular type, for specialized structures like the furnace or even something as mundane as a roof, may lead to the absence of that type of stone within the stockpiles. This would in turn skew interpretations as to the origins and potential interactions during a period because stones of a particular area may be disproportionately represented or absent in different piles of stone. The exotic stones in other structures may be there for more arbitrary reasons, but their use would have essentially the same archaeological consequence. The only real difference would be that the larger structures, whether specialized or not, would require far more ballast and would therefore have a larger impact on the distribution of ballast types.

Lazareth and Mercier (1999:124, 136) explained the lack of mixing in the walls and other generic structures as being the result of ships sailing straight to the ports in which the structures were built. The ballast was then unloaded onto land and used for construction shortly thereafter.
Their explanation makes sense in this case; given the relatively short distance over which the stones were carried, the ships may not have had to stop. Over longer distances, however, a ship may be required to stop at multiple ports to resupply and/or trade. In these cases, a different explanation for the lack of mixing makes more sense, especially if the amount of stone in a structure is more than could be carried aboard a single ship.

If the stones were truly desirable to those in charge of building the various structures, the explanation for the lack of mixing may be that the stones were just as much cargo as they were ballast. If captains knew the stones they were carrying were worth something at a particular destination, they may have put effort toward gathering a particular type of stone and keeping them separate from the rest. This seems more likely with the stones used in the construction of specialized structures, such as the foundry, which require certain materials, as opposed to a wall, foundation, or road which could be made of nearly any available material. However, it may be just as possible in either case, especially if those paying for the construction are very particular and can afford to import stone.

Stones so desirable as to be actively imported include types like Caen stone, which is limestone quarried from sites near the city of Caen in Normandy, France (Blows et al. 2003:1143). This particular type of stone was desired throughout Europe for its color, texture, accessibility, and the ease with which it could be shaped and carved (Holmes and Harbottle 2003:202-203). Caen stone has been identified in structures and sculptures built as early as the first century A.D. and as recently as 1955 (Buckland and Sadler 1990:119; Holmes and Harbottle 2003:202-203). Over that period, Caen stone was used in sites across Europe and later shipped over the Atlantic to Bermuda, Canada, and the United States.
While the stone may have been carried overland to those sites closest to the quarry, it was likely more economical, less time-consuming, and sometimes necessary to transport the stone to distant locations by ship. In England alone, the large buildings for which Caen stone was used included churches, cathedrals, abbeys, and many other types of structures (Holmes and Harbottle 2003:202-203). The larger of these projects required multiple ships and shipments to transport the essential amount of stone. In one case, during the mid-eleventh century A.D., a fleet of fifteen ships was tasked with importing a large amount of Caen stone (Buckland and Sadler 1990:119). In some cases, the stones were partially processed (i.e. shaped and carved to some degree) before such large shipments in order to reduce both the amount of excess stone and the cost (Holmes and Harbottle 2003:202). Such pre-processing, as in shaping or sorting, may not have always been necessary and could have occurred after the stones had been discarded.

Another explanation for the sorting of stone in the structures is the intentional sorting of stone in stockpiles after being removed from the ship. If this occurred, it could result in features much like those seen at modern stone suppliers. In some cases, sorting may have been performed more out of necessity; for example, it may have been necessary to sort through ballast from ships on which Caen stone was included among the ballast, as opposed to explicitly being carried as cargo (Buckland and Sadler 1990:119). At the time, any sorting may have gone no further than the removal of a particular type of stone; however, even this removes stone from certain facets of the archaeological record. Such a practice could easily have been extended to other types of stone in order to fit any needs of the surrounding communities.

If builders or their overseers visited a location at which the stone had been sorted and saw a type of stone they liked, they may have chosen to use it for no other reason than preference, especially if the stone was to be used in a structure which did not require the stone to have
particular features. As the builders used up certain piles of stones, they may have then switched
to the next pile of different stones without really considering the difference in appearance.
Additionally, if any ships were carrying a single type of stone, whether by chance or design, each
delivery may have been piled and used separately; even adding it to a communal pile of stone
may still result in structures of unmixed stone if those collecting the stone take it only from a
portion of the pile containing a single type of stone. Considering the amount of activity
surrounding an established port, and the potential need to rebuild or rework buildings or plots of
land as requirements change, any evidence of stone sorting or stockpiling may be buried, non-
existent, or indistinguishable in many locations.

While stones are being transported aboard ships, whether or not they are intended for
sale, even the most general nature of their intended purpose may not be immediately identifiable.
Of the visible features of a stone, any evidence of carving or shaping may lead to the immediate
classification of it as a commodity which was being transported by the ship. Even such features
may only be present because the stone on which they appear is rubble reclaimed for an unrelated
purpose. Just as with the ship travelling from Punta Villarica, if the intentional transportation of
stone was not documented, potential archaeological investigations involving the wrecks might
not recognize the value of the stones, especially if they were not modified before they were
shipped and their use and value are not widely recognized. The features of the stones themselves
are not the only indication of a potential appeal; section 5.3 outlines general features of a ballast
pile which may be indicative of a ballast cargo
Stowage

Of the practices discussed in this thesis, stowage is the primary one which may work in favor of an archaeologist attempting to study ballast. The need to securely stow objects may mean that, depending on the level of preservation and the circumstances surrounding the ship becoming a shipwreck, the ballast may be in nearly the same position as it was when the ship was active. The result being that features such as stratigraphy or evidence of particular arrangements of ballast could be preserved within the remains of the ballast pile. Over extended periods, such features may exist and be maintained within an active ship; however, the ongoing process of stowing items may have a destructive effect. This is because stowage is influenced by the potentially high degree of variability in cargo densities and distributions as well as the need to replace and redistribute cargo and ballast as items are loaded and unloaded.

Depending on the extent to which the ongoing process had influenced the placement and rearrangement of stones within the hold, what archaeologists observe may be a complex palimpsest of stones, if any observable features remain. Regardless of the exact processes which influenced the final configuration of materials in the hold, even if the condition of the ballast pile is perfectly preserved, much of the information recovered from the pile may be indecipherable. This does not mean that any features are useless; however, as the next section will discuss, what these features could signify must be considered very carefully.

Potential Features of the Ballast Pile

If the practices described in this thesis have not resulted in the complete disturbance of a ballast pile, there may be some identifiable features. When considered alone, the idea that stowage could preserve features may give archaeologists some confidence as to the validity of visible features in any given shipwreck. When the other practices are taken into account, it
becomes apparent that any preserved features may not represent the events or connections to which they could be associated. The forms which these features take can include stratigraphy as well as small or large groupings of a particular mixture or type of stone which may appear as pockets, lenses, or portions of ballast partitioned away from other stones. It is also possible that no features will be evident in some or all areas of a ballast pile.

To illustrate the potential complexity of a ballast pile, the hypothetical configurations of a single ballast pile can be examined. For example, if it were possible to take a core at any spot in a ballast pile, the resulting sample may show two or more distinct layers. An additional core from a different area of the ballast pile may show entirely different stratigraphy, possibly containing stones which were not visible in the first core. Repeating this process could show numerous arrangements of stone and other materials within a single pile. If the same site was completely excavated and carefully recorded, what appear to be layers in a single core may in actuality be groups of ballast which primarily occupy a small portion of the pile. There are at least three explanations for features of this type which can be drawn from the effects of the various practices.

The first explanation is that each grouping represents a loading event at a different port. Each event could appear as a pocket of stone, rather than a layer extending the length and breadth of the ballast pile, as a result of the potentially asymmetric distribution of cargo and the need to use ballast to compensate for any instability this may cause. The second explanation is that the features were produced during a single loading event. Distinct features may result if ballast is carried to the port from numerous stockpiles and loaded from small boats into different areas of the hold. This could give the appearance of a well-traveled ship when, in fact, the ship may have foundered on its maiden voyage.
Where the first explanation is the logical result of frequent stops during a voyage, the second explanation may give the same impression with only a single stop. The second explanation appears to be partially demonstrated by the Luna documents. In addition to ballast being shipped and carted in from Punta Villarica, various merchants were paid to cart stone to the docks from within the city and multiple captains were paid for a portion of ballast from their ships (Childers 1999:126-127, 174, 188, 229, 238, 239, 240). Portions of even small purchases could end up on different ships as the stone is moved to the docks and loaded where necessary.

The third explanation is that the stones in any visible feature may be purposefully loaded and kept separate with the intention of either delivering them to a prearranged buyer or selling them at an undetermined time in the future. The stone may be known to be desirable or the captain may simply find it interesting and hope others will like it enough to buy it. This has been discussed in some detail in sections 2.2.2 and 5.2.5 yet it is important to reiterate that such stones may not have any qualities which archaeologists could recognize as unique and desirable. The stones may only be desired as a result of the aesthetic choices of the buyer or simply because they are stone, regardless of their other characteristics.

This last reason may adequately describe the stone aboard the ship which carried seven and a half tons of stone from Punta Villarica to Veracruz. The stone did not have to serve any special purpose other than as future ballast. Without records its value may not be recognizable. If ships ever sank while involved in the direct transportation of stones which archaeologists recognize as being valuable, as fourteen of the fifteen aforementioned Caen stone transports did, their general intended purpose may be definable with some certainty. However, stones with no known value may be dismissed as worthless ballast, even if they were not. There may be no way
to remedy such errors except by slowly building on the gathered knowledge regarding the 
functions of stone during a given period.

When considering the means by which stones can reach a port before they are loaded 
onto a ship, distinguishing between the three types of events may not be possible without other 
sources of information. The third type of loading event may be discernible only if the stone is 
known to have been valuable or is partitioned away from other stones. Such partitions were 
probably neither used nor practical as they would limit other activities involving the 
rearrangement of cargo and ballast and could potentially be costly to produce and install. In any 
of these three scenarios, the stones themselves may consist of reused stone and would not 
necessarily signify that the ship they are found on had ever visited the locations from which the 
stone was gathered or sold. The last point is true for any identifiable feature, whether they are 
groupings of stone or stratigraphy.

It seems unlikely considering the many ways in which ballast is moved and the factors 
which determine its placement, but if the conditions are right, the same processes that led to the 
creation of small groupings of ballast could potentially result in groupings which span the hold. 
Although some researchers have remarked on the potential usefulness of stratigraphy, a 
stratigraphic feature matching the type described here was not recorded in any of the many 
documents examined for this thesis. Additionally, the potential for stones within a layer to 
become mixed with other stones over time or to come from a mixed or reused source could mean 
any apparent stratigraphic relationships between layers may be neither useful nor truly 
representative of the spatial or temporal connections they appear to signify. Such rock-type based 
stratigraphy may not exist in the way that archaeologists hope, but if the manner of loading 

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ballast by size, as described in section 5.2.3 on permanent ballast, is applied to an archaeological site, a different type of stratigraphy becomes apparent.

In William Lamb’s (1988:51-53) discussion on the features of the MRW ballast pile, he noted a lack of any stratigraphy based on the distribution of rock types in the walls of trenches excavated through the site. In the same discussion, however, he notes a concentration of large stones on the west side of the ballast pile with smaller stones to the east. This could mean when the ship settled on the bottom, it came to rest on its side with the keel to the west. If this is true, it means when the ship was upright, the larger stones were placed at the bottom of the hold and overlaid with smaller stones. This arrangement fits both Lamb’s definition of permanent ballast (Lamb 1988:6) and the possible method of loading described in section 5.2.3 of this thesis.

In addition to the sorting, Lamb (1988:51-53) noted concentrations of particular stone types which appear to match the features described earlier in this section. Unlike the sorting, the groupings of rock types are oriented horizontally, along the ship, rather than along what would have been the vertical axis when the ship was afloat. For example, calc-schists are primarily found at the north end of the ship, some basalts are more concentrated at the southern end, with limestone being more concentrated in the amidships. The larger stones on the west side are composed largely of basalt and limestone. Other stones, such as the quartzites, are found equally throughout the ballast.

The distribution of the different types appears to be partially linked to their size. As stated earlier, the larger pieces of basalt and limestone were most concentrated at what could have been the keel (Lamb 1988:51-53). The stones in the rest of the ballast pile are mostly small to medium sized. The types which include medium-sized stones, such as the calc-schist and limestones, are mainly found more to the east of the large stones. The smallest stones, including the quartzites,
were not concentrated on the east side of the ballast pile as might be expected. Instead, they are dispersed evenly within the ballast pile. To varying degrees, the same types of stone seen in the concentrations are also found in other areas of the ballast pile.

When compared to their distribution, the size ranges for the different rock types match what might be expected if the archaeological effects of the practices are accurate. Size and type sorting and the resulting features would be the result of loading techniques; large stones could be loaded first, then medium stones, followed by smaller stones which fill the gaps and reduce the amount of unused space within the ballast pile. Different types of ballast being grouped in a particular area the result of stowage may have resulted from the order in which loads of stone arrived at the port, the need to replace heavy cargo with ballast, and/or loading cargos of stone in a particular area to allow them to be accessed or kept track of until they were unloaded at their destination.

The final type of feature is a lack of distinguishable features. This may be the result of a recent careening, cleaning, or the replacement of a heavy cargo with ballast. The ballast could be from a single source which may be more or less homogeneous even if the stones are from numerous sources. Conversely, if ballast is replaced with rocks from a beach or river, many rock types may appear within the pile, yet if chemically analyzed, the results may point to a specific region of which only a small portion may be accessible to the crew of a ship. To some degree, the lack of features may be the result of stowage; as ballast is moved within the hold, it would almost inevitably become mixed with other stones which could obscure features.

Based on the distribution of rock types in the unit excavated through the EPII ballast there do not appear to be any features. This is also demonstrated by the analyzed samples; stones from the same source are found at all levels of the unit even though at least one change in ballast
was suspected to exist. The addition of a single load of ballast, which is recorded in the Luna
documents, could have resulted in a layer of unique stone on top of what was already there
(Childers 1999:221; Yugoyen 1569:496-497). The absence of such a layer may be explained if
the load of stone was isolated to a different area of the hold and/or been composed of the same
types of stones as the rest of the ballast pile. Unfortunately, the ballast recovered from EPII is
especially a large core and is not necessarily representative of the arrangement of stones in the
rest of the ballast pile. Had the unit excavated for the purposes of this thesis reached the hull, it
might have shown a similar distribution of ballast sizes. From what was excavated, there is a
consistent distribution of sizes throughout the pile. All levels included ballast of various sizes
which would be expected if medium to large stones were loaded and then small stones were used
to fill the gaps.

At this time, it is not possible to tell if the remainder of the ballast on the site is from the
same source or from a variety of locations because only a single type was sourced. However, the
presence of Caribbean coral intermixed with basalt from the Canary Islands can be taken as an
indication that ballast from at least two sources was mixed. The only way to begin understanding
how the coral relates to the basalt and the rest of the ballast is to analyze other types of stone and
determine how their source(s) relates to the maritime and terrestrial landscapes of the period. As
with other features in a ballast pile, to determine the extent to which a ballast pile is
homogeneous, the whole pile may have to be excavated and recorded.

The need to excavate more than a single area of any ballast pile is illustrated by both the
MRW and the Yassi Ada wreck. The distribution of sizes and types visible in the trenches
through the ballast pile of the MRW would not be comparable if the ballast in only a single
trench or unit had been examined (Lamb 1988). Even if a single trench extended the entire length
of the shipwreck site, certain features, such as the concentration of large stones on the west side and the trend toward smaller stones to the east might not be visible. While the currently available information on the ballast pile of the MRW is far from complete, what is available offers a more complete, and tangible picture of the potential features of a ballast pile than any other ballast study.

The ballast aboard the Yassi Ada wreck demonstrates essentially the same idea. If the ship had gone on to other ports, and sold its cargo, it may have been necessary to add small pockets of ballast to replace the weight lost by removing cargo. In an extreme case, all the amphorae could have been removed from the hold at a single stop and replaced with ballast at the same port. Where Bass and Doornick (1982) were able to easily see the small amount of ballast stones because they differed so much from the surrounding material, archaeological excavations on a wreck full of ballast may not have noticed such a small concentration of stone unless units or trenches were placed on the correct portion of the wreck.

The features of the shipwrecks which are mentioned in this section are not adequate enough to conclusively support the existence of the various types of features. For that reason, the features described in this section, or lack thereof, largely remain the hypothetical results of the practices described in this thesis. Most of them were not recorded in the available ballast studies, but they are the logical products of the various practices. Identifying the extent to which any features may exist will require an increase in the number of ballast piles which are carefully excavated to find both the artifacts they contain and the arrangement of the stones of which they are composed. The potential complexity surrounding the presence of the features is not only influenced by the practices described so far; there may be other processes which only serve to confound interpretations regarding ballast.
Other Sources of Archaeological Uncertainty

The actions of the crew and the manner in which they carry out the practices described in this thesis appear to be the primary source of uncertainty when it comes to interpreting the relationship between shipwreck and its ballast in archaeological investigations. When considering the sources from which ballast is collected, including natural sources and merchants, other means by which uncertainty can be introduced into the study of ballast must be considered. The general means fall under two categories: natural and cultural.

Natural Sources

For any given stone, the natural sources of uncertainty include any natural process which acted on it before and after its use aboard a ship, the latter including time spent on the seafloor after a ship discards the ballast or sinks. The processes may include the movement of stone by rivers, creeks, landslides, glaciers, or other similar forces. The stones themselves are another potential source of uncertainty; the processes by which they form vary in terms of the specific amounts of various elements and compounds which they introduce to the stone. The resulting stones may differ very little in both appearance and composition from stones which formed on a different continent and billions of years prior; what may link a stone to its specific source is the stone’s age. The composition and measurable age may be chemically altered by pressure, heat, or exposure to different environments after the stone has formed. Of these forces, problems associated with glacial erratics and compositional issues have yet to be addressed and will be discussed in this section.

To some degree, the movement of stones by creeks, rivers, and landslides can be accounted for since these processes are confined to a single drainage basin through which they flow. Glaciers are not always so limited; at various points throughout Earth’s history, large
glaciers called ice sheets covered much of Canada and portions of the northern United States (Davidson et al. 2002:410-419). As they moved slowly over the land, the glaciers carved out some of the features we see today, including the Great Lakes of the Northeast and Puget Sound in Washington State. Any stone which is displaced to form such features may be picked up and carried great distances until the glacier begins to melt and releases the captured stones. These stones, which can be anywhere from silt to house sized, are deposited into entirely different environments as the glacier melts and recedes.

Understanding the impact of glaciers on the movement of stone is not necessary for many parts of the world; however, it remains a relevant issue in any area which has interacted with cultures in glaciated regions, regardless of how tangential those interactions may seem. For example, researchers in the United Kingdom have identified glacial erratics as one of the potential explanations for the presence of certain stones in the structures they have examined (Buckland and Sadler 1990:118; Hoare et al. 2002:101-102). If at some point those stones were loaded as ballast and carried to the Caribbean before the ship sunk, not recognizing the effect of glaciation on the collection sites of those stones may lead to erroneous conclusions as to how they ended up aboard the ship.

The other natural source of uncertainty which has not been addressed is inherent variation in stones as a result of their formation processes and subsequent forces to which they are subjected. When forming, the basalts, granites, and other igneous rocks begin as molten rock which penetrates the Earth’s crust and makes its way toward the surface (Davidson et al. 2002:80-97). As it moves through the crust, the magma will melt some of the surrounding material with which it comes into contact. The melted material is absorbed by the magma which changes the composition of the magma, thereby modifying the ultimate rock type. The
distribution of minerals, including those which were in the rock initially and any which were later assimilated, is not homogeneous and may change as the magma cools.

As a pocket of magma cools beneath the surface, the minerals which crystalize at higher temperatures will settle to the bottom through the remaining molten minerals (Davidson et al. 2002:88). The result can be a range of rock types with varying compositions within a single rock formation. To some degree, even rocks which were once directly adjacent to one another can also vary slightly in composition. The same processes which formed any given stone have occurred throughout Earth’s history. In some cases, this results in rock formations with very similar compositions despite being separated by thousands of miles and millions of years. The only way to differentiate between the stones may be by their ages which may also be affected by natural processes.

After a stone has formed it may be exposed to forces which alter its basic characteristics. These types of changes are what define the metamorphic rocks. When rocks are exposed to heat and pressure, the different minerals composing them may begin to soften or melt (Davidson et al. 2002:107-113). As a result, chemical reactions and a reorganization of minerals within the rock change its composition and appearance. This also results in the loss of the daughter elements which are used to radioactively date geologic material, thereby resetting the measurable age of the rock to its most recent recrystallization rather than its formation (Davidson et al. 2002:171).

Different kinds of changes can also occur when a rock is exposed to certain environments. For example, during excavations on EPII, some of the ballast stones fragmented while being excavated and during processing in the lab. The remains of these stones make up the indeterminate material described in section 4.1. The stone shown in Figure 4 represents a stone which maintains some integrity but can be fragmented with very little effort. The loss of integrity
may partially be a result of the stones’ prolonged exposure to salt water. The salt and other minerals dissolved in the water may have penetrated and reacted with the stones which, in this case, caused them to degrade and fragment while altering the minerals in affected portions of the stones. In order to avoid some of these sources of uncertainty, the samples which were chosen for analysis from EPI and EPII were igneous rocks which had not undergone any visible alterations and retained fresh material at their core.

To learn the most about the unaltered portions of the ballast stones, it was necessary to subject them to both geochemical and geochronological analyses. Combining analyses resulted in a better comparison of the samples from the wreck and potential sources. The analyses allowed for some reinforcement of conclusions regarding the source of a stone while being able to eliminate other sources with just as much certainty. For example, in Figure 5, the sample from EPI shows a similar composition to the samples from EPII. Based on those diagrams, it could have been argued that the stone from EPI was also from the Canary Islands; its position is also within the range of rocks found on many of the islands (Carracedo et al. 2002:464). What sets sample 94-97L apart is its age; it is over one billion years older than the samples from EPII and could not have formed on the islands. It was therefore necessary to expand the search to other areas of the world until a formation with a similar age and type was found. Ar-Ar age determination also aided in determining the possible sources of the stones from EPII. Numerous locations around the globe contain the same type of basalts; however, no other sites contained basalt of the correct age and were therefore rejected as the source of these particular stones. Without knowing the age it would be difficult to exclude such sites, some of which are located within the range of Spanish exploration.
Before either the dating or geochemical analyses are performed, it is necessary to make thin-sections of each rock. These can be used to get a more detailed look at the composition of a stone, or, as was their primary function for this thesis, thin-sections were used to verify the unaltered nature of a sample. Any alteration could alter the composition of a stone, thereby making it impossible to accurately source based on age or composition. Ultimately, the types of analyses performed, the extent to which a rock of any given type or age is present across the globe, and the amount of available research concerning outcrops will influence the certainty with which sources can be identified.

*Cultural Sources*

While the effects of nature are somewhat predictable and can be accounted for to an extent, the effect of countless humans and their eccentricities may be largely unpredictable and can create what could be referred to as cultural erratics. These would be stones which have been taken out of context(s) and carried long distances by humans before use or deposition in their final, and later archaeological, context. These stones may give the appearance of a direct connection where, in fact, there is a convoluted and untraceable trail involving travel over both land and sea. Cultural erratics may find their way onto ships anytime a stone is carried to a seaside location by either maritime or terrestrial means.

Once a stone is put into a position which may result in its placement aboard a ship, it has the potential to enter into a web of interactions spanning the extent of the contemporary trade network, which includes any terrestrial locations with direct or distant connections to the sea. Within the maritime context, those purchasing or collecting ballast may not decide to, or be able to, exercise control over the types of stone which are loaded onto their ship. A captain could limit his voyages to the ports controlled by his country of origin, yet, if any of his ports of call
reused ballast, he may still unknowingly find his hold filled with stone from any port in the world with even the most tenuous connection to his own. Stones from areas which have not been visited for hundreds or thousands of years may be found among the ballast of a functioning ship if the stone is not lost during the potentially numerous cycles of reuse. Such stones may be taken from former ballast dumps, stockpiles, or structures like Kisimul Castle.

The idiosyncrasies of human acts also affect the procedures they perform. Modifications may be made to the prevailing practices of a period by certain groups or organizations. For example, according to an account written in 1819, at one point the British careened their warships every three years (Goelet 1986:14). Other groups may have done it more often if transporting food or delicate cargo aboard smaller ships without a dedicated hold for ballast, and others may have done it less often, whether to save money or because they did not mind the filth. The basic purpose of careening and other practices may remain unchanged while the exact methods and frequency vary from ship to ship or person to person. The same variation in habits may lead to the introduction or removal of stone types from a maritime context. Section 5.2.5 addressed how ballast may be removed; the following discussion shows how unrelated material may find its way onto a ship.

To best illustrate the manner in which extraneous ballast may end up aboard a ship, it is useful to look at the potential sources of other types of artifacts. An unstated assumption regarding the artifacts, including ballast, of many shipwrecks is that they are directly associated with the ship and its history; however, there are three potential sources for artifacts found in the ballast of shipwrecks. The first source, which fits with the assumption, is the sailors and other people who visited or lived aboard the ship while it was active. The second source is ballast material which is reused or collected from previously occupied areas and may include artifacts.
not related to the vessel or the period in which it functioned. The third source is contamination by modern or unrelated, intrusive artifacts introduced to the shipwreck by people or natural processes.

Efforts to differentiate between artifacts from the first and second sources may be exceedingly difficult unless an artifact is obviously anachronistic. Examples of easily identified anachronisms have been found at a few sites, some of which can be explained in terms of maritime transport. At various sites along the Atlantic coast of North America, coins, including some of Roman and Greek or Italian origin, have been recovered by archaeologists (Hume 1974:121-124). Rather than assuming that ships from the cultures in question made the trans-Atlantic voyage, the seemingly unrelated artifacts may be explained by the captain’s ballast collection site. A likely explanation for the presence of some of these coins is that ballast material was collected from the shore of the River Thames near London, England and then unloaded, coins and all, onto eastern shores of North America.

Similar circumstances may have resulted from other frequented locations like the site at Hengistbury Head. If items were intentionally or accidentally dropped by a crew unloading cargo or anyone else visiting the location, the objects could later have been inadvertently loaded onto a ship as gravel was collected from the shore. This is further complicated by the removal, addition, and movement of ballast as conditions change and cargo is loaded and unloaded. If the artifacts introduced with the ballast were not already mixed with other artifacts at the time of loading, the movement of ballast and the subsequent deposition of artifacts from the first source would potentially change their apparent archaeological context.

The identification of artifacts from the third source could be relatively easy as the items may include objects and materials which were either not used or not available during the period
in which the ship was functional. Even a shipwreck which is completely buried in sediment at the time of discovery may have been partially exposed and reburied repeatedly over the centuries. This can result in a slight movement of artifacts from their original context, but, more importantly, it may allow unrelated artifacts to penetrate the site (Horlings 2011:278-279). Modern material carried by the same forces which eroded the area may settle onto the site before the exposed portion is reburied. Artifacts may also penetrate the site if they come to rest on top of the sediment and slowly work their way down as the sediment is agitated by currents and waves (Horlings 2011:218). The site can remain largely undisturbed as contemporary and modern artifacts travel through the surrounding material. Stone introduced to a site through the same processes would not necessarily be so easily identified.

This issue was mentioned in section 2.1 in the discussion on the use of sand as ballast. When sand found within a shipwreck was compared to the material on the seafloor, it always matched the local material (Laures 1986:167). Depending on the environment in which the shipwreck resides, it may be possible for pieces of stone larger than sand to be deposited on the site and work their way into the wreck in the same manner. Even shipwrecks like EPI and EPII, which are located in an area with no natural stone outcrops and no naturally occurring grains much larger than sand, can be contaminated by ballast discarded on the site or as a result of the addition of fill material used to extend the shoreline. Both of these activities occurred within Pensacola Bay, but, fortunately, neither activity appears to have occurred in the immediate vicinity of the wreck. The only rock piles in the area are those associated directly with the shipwrecks and the area has not been filled as the wrecks are both at least half a mile offshore.

If stones are suspected of being introduced to a site, whether naturally or by human activities, they cannot immediately be dismissed as invasive material. While some may fit this
classification, it is entirely possible that the ship acquired the same types of stones when it stopped at various ports or during a previous stop in the location at which it wrecked. The stones must therefore be considered carefully in terms of the maritime and terrestrial contexts of the time before determining their relevance to the ship in question.

The point of this discussion on the potential unreliability of artifacts and ballast is to further illustrate the possibility that ballast unrelated to the history of the vessel may be found in the hold. The problem with ballast is that, unlike the artifacts in the previous examples, it could be much more difficult to identify stones which are unrelated to a particular period. Just as coins discarded on a shoreline could end up being transported across the ocean in ballast, so could any other type of artifact, including stone, be removed from its context and carried indeterminate distances. One of the main differences being that stone is generally far more durable and much older than other artifacts and may therefore embody a history spanning continents and millennia.

**Conclusions**

After considering the many facets of society through which a stone may move, the answer to the question, “What can be learned by studying stone ballast?” is hardly simple. Aboard a ship, the function of ballast is relatively straightforward; it functions as deadweight and may be left largely undisturbed for years at a time. When considered in relation to relevant practices and potential roles in other contexts, the apparently simple function belies a level of complexity which is not thoroughly considered in previous discussions of ballast. Unless a stone is used to build an undisturbed structure at the outcrop from which it originated, the possible paths from one point to another branch almost endlessly; the situation is only exacerbated by the addition of ships. With each new function a stone takes, its previous role(s) may be lost unless they leave some sort of evidence which resists erosive forces encountered later in the life of the
stone; such evidence could include alterations, mortar, concretions, or wildlife. In the end, the only definable features of a stone may be its source, its final use, and the general means by which it could have reached the latter.

The certainty with which archaeologists can associate ballast in the hold to locations visited by the ship will vary greatly depending on what is already known about the ship. Alone, the presence of ballast from a certain location may not be significant beyond possibly narrowing the potential context of the ship. With historic records and other artifacts pertaining to the ship, such as a ship’s log or port records, ballast may be used to corroborate known links. Without any available records, maritime archaeologists may only see two points: the source and the ship’s final resting place; other points may be inferred based on known interactions in areas between these locations but cannot be known with any certainty, and in no way do these points necessarily indicate anything resembling a direct line of travel.

For example, stone can come from a natural source, be carried thousands of miles along a convoluted path by both human and natural forces, get loaded onto and later unloaded from a ship, be used as a building stone, reused as ballast when the building falls into disrepair, then end up on the bottom of the ocean as a feature of a sunken ship hundreds of years after it was initially collected. Even stone which is collected and lost within the lifetime of the ship on which it is found may take a very different route through the economy, much of which may be, at best, vaguely related to the ship. It is entirely possible that none of the intervening steps between source and shipwreck will be reflected on the stone, yet all affect when and where a particular stone is ultimately deposited and which ship brought it to that location. Archaeologists who source a stone but cannot see these steps, especially any steps which kept a stone in a static and completely unrelated context for decades or centuries, may inadvertently make connections
which did not exist in the manner or at the time reflected by the stones. These connections may in fact exist as the archaeology shows but the manner in which the ballast arrived at that location may be lost.

Additionally, because there is generally no immediacy in the use of a stone, a stone in nearly any context may remain available to anyone who happens to come across it in the future. What is, or was once, part of a wall may sit still for hundreds of years before it is used as ballast, or to build a different structure, without the slightest change in the stone itself. This is not always true; depending on the type of rock and what it has been subject to, a stone which once seemed unbreakable, may easily shatter, or crumble at a touch, as some of the ballast aboard EPII did during and after excavations. In the short term, a stable piece of ballast can become fouled in the hold of a ship or while sitting on a shoreline. To many it may appear worthless, but to a merchant who is aware of stone’s longevity, it could be an investment which will regain some value once clean. Should a stone break in half, the halves do not suddenly become useless, there are simply two stones where there used to be one. Even if a stone loses its integrity and crumbles, its potential for use does not necessarily diminish, as even gravel and sand have a purpose. For these reasons, the durability of stone, including stony coral, makes it a poor indicator of fine-grained interactions.

In many ways coral may prove less useful as an indication of specific interactions than other stones. Particular stones may be limited to a small region and the area from which they could have been collected may be narrowed down even more. Coral may be much more difficult to source to a single location because of the process by which it reproduces and the large region over which a single species may spread. However, where rocks may require expensive analyses to source, coral may be identified and narrowed to a general region (e.g. Caribbean, South
Pacific, etc.) with only a few pictures. While coral does not appear to be particularly useful for archaeologists beyond its role as a general indicator, it should not be completely ignored; even a general indication as to the potential context and movement of a ship is important, especially when the identity and/or origin of the vessel are unknown.

The types of interactions which may be most useful for piecing together maritime trade routes based on the movement of stone are those discussed in the study performed by Lazareth and Mercier (1999). The presence of large amounts of stone from a single source within a structure may represent the intentional transportation of stone cargo as opposed to the potentially random redistribution/reuse of stone ballast. If the amount of former ballast stone in the structure is more than a single ship could carry, it may be the result of a relatively long-term stone shipping operation. Long-term in this case meaning multiple shipments over however long the voyages took, as opposed to a single discharging event which may not involve deliberate trade interactions on the part of the captain. In addition to features which exist in terrestrial structures, any shipwreck could include evidence in the ballast of the intentional shipment of stone and other practices.

When examining the features of a ballast pile for evidence of practices, the problem may not be whether a particular feature is evident; rather, the problem would more likely lie in determining the actual practice which resulted in the creation of the feature and how that relates to the history of the vessel. Additionally, the basic qualities of the features, i.e. the stones of which they are composed, require careful examination. It may be necessary to identify the relationship of ballast stones to others in a feature or to the rest of the ballast pile. Adequately determining such relationships may require in-depth geologic analyses even if the stones visually match types from a suspected source location. Such analyses could both confirm associations and
reveal any stone types which appear to, yet do not, match stones in a particular region. The presence of multiple, seemingly unrelated rock types within a feature could be the result of the reuse of ballast which was mixed with types from other sources at some point in its use. Ships like the *La Salvadora*, which may not have been reballasted during its only voyage, and the *Vasa*, which was not afloat long enough for the ballast to need replacing, may reveal the most about where ballast was collected in established ports and what types of features to expect on ships which have not undergone months or years of hold reorganization.

Ultimately, any conclusions which are reached regarding the relationship of the ballast to the history of a particular vessel will be very limited. Only the most general interpretations pertaining to maritime interactions as a whole may be made with any confidence. Anything more specific may not be possible without correlating ballast analyses with records directly associated with the ship. Even then, interpretations can hardly be more than speculative except under certain circumstances, such as those shown to involve the direct transportation of stone. Additionally, it may not be possible or useful to directly evaluate the effectiveness of any study involving ballast against that of another shipwreck. Variation within all the practices, such as how often different procedures were performed or the precise methods used, would have existed depending on which nation they had been developed by and how the captain had modified them to fit his needs, his ship, and the current circumstances. Methods for the study of ballast and the prevalence of different features may be compared but each type of feature, and each individual feature, could potentially represent the effects of a variety of unrecorded and potentially indeterminable circumstances.
**EPI and EPII**

When the many sources of uncertainty when dealing with ballast as the primary source of information are considered, it is difficult to come to any conclusions regarding the ships. This is especially true of EPI, primarily because only a single unprovenienced ballast stone from the wreck was analyzed. Even so, if the provenance in Brazil is accurate, the presence of the stone on a ship which sailed across the Atlantic Ocean for the expedition, and which may never have visited Brazil, may have important implications for future ballast studies when it comes to determining the means by which a stone is introduced to a ship and the economy. Researchers may be required to look beyond the region in which their ship functioned and to any other nations with which their ship’s nation interacted. Future research may reveal that the ship never visited the locations to which the ballast creates a link.

The same is true for EPII; even though the analyzed ballast matches stone from the Canary Islands, none of the available records indicate that EPII ever crossed the Atlantic. While is it entirely possible that the ship stopped at the Canary Islands at some point prior to joining the fleet, it is potentially just as likely that the ship took on a load of stone in the New World which contained large amounts of basalt previously transported over on a different vessel. If this was the case, it would also partially explain how coral came to reside in all levels of the ballast pile. The opposite may also be true; if the basalt was loaded while the ship was stopped at the Canary Islands, the small pieces of coral may have been discarded by a ship which crossed the Atlantic and were then loaded along with other small ballast in order the fill any gaps between the basalt. Determining the means by which the different types of ballast were introduced to the ships is not possible without learning more about the specific actions of each ship. This does not make the
information about the ballast useless, but it does reinforce the need to carefully and thoroughly study the ballast, and possibly extend any research into the activities of other nations.

The lack of features and the apparent mixing of stone from different sources within the unit excavated into the ballast pile may be representative of the entire pile and may exist for a few reasons related to where and how the ballast was acquired. The first is mentioned in the previous paragraph; ballast is carried between ports and then reused along with other ballast. The second reason is much the same yet takes place on a larger scale. As shown in the Luna documents, it was occasionally necessary to transport stone from nearby settlements to supplement local sources of stone. The result may be a mix of stones which have no relation to the port at which they are loaded onto a ship and would not show a connection if examined by archaeologists. The final reason is the hurricane itself; there is the distinct possibility that the storm which smashed the ship against the sandbar in which it currently rests was violent enough to cause items in the hold to shift and become mixed to some degree. The lack of features may be fairly typical aboard ships which were active during periods of intensive maritime exploration and trade especially if they were travelling to many ports throughout a nation’s sphere of influence. The only way to answer any questions relating to the origins and prevalence of features as well as the many other questions which this thesis cannot begin to address is to continue researching the ballast of all shipwrecks, thereby constructing a better framework for the continued examination of shipwrecks and their contents.

*Potential Avenues of Research*

In reference to the Emanuel Point shipwrecks, there are a few ways in which the research of this thesis may be advanced. To begin with, a more thorough series of geologic analyses, performed on multiple types of rocks, may reveal more about the possible movements of the
ships, the sources of the various types of stones, and general practices of the time. For example, some of the basalt dikes in Brazil, from which the EPI ballast may have been collected, intrude through granulites. Additional analyses may reveal if the granulites in Brazil match those recovered from EPII or if they were gathered somewhere on the other side of the Atlantic Ocean. Similarly, the other rocks types could have been collected from any number of locations which may or may not be related to each other. Any analyses could also be extended to stones of different sizes; examining sand from the deepest portions of the hull may reveal if the sand is from a different location or if it permeated the ballast after the ship wrecked.

To accompany the analyses, and potentially reveal features of the ballast pile which the excavation for this thesis did not encounter, it may be useful to excavate additional portions of the wreck with ballast as one of the focuses. This could involve additional units or trenches which traverse the wreck in multiple directions, and would potentially reveal site-spanning features just as William Lamb’s analysis did (Lamb 1988:51-53). For example, the unit which was excavated for this thesis showed no evidence of the boat-load of ballast which was loaded in Veracruz. Excavating additional units may reveal that the ballast from Veracruz was no different from the rest of the ballast or that it was loaded in a single portion of the hold to offset items elsewhere in the hold. While further excavations and analyses may not seem useful when considering the level of potential uncertainty associated with ballast, even a tentative history is better than no history and may provide clues for future research.

Additional archival research pertaining to the ships and the established Spanish ports may be even more revealing. Thorough examination of the records from Veracruz, Punta Villarica, and other cities in the New and Old World may reveal where the Spanish were acquiring ballast, how it was stored and used, how often different procedures were carried out in the ports, and
how a particular port’s practices may have affected what archaeologists observe in shipwrecks. As more details relating to the movement of the ships and stone are gathered, the results of geologic analyses could be compared to the movements of the ship in order to better understand the degree of the relationship between a ship’s movement and the ballast it contains.

In maritime archaeology as a whole, advancing the study of shipwrecks and their ballast will require a much more widespread examination of ballast and ballast piles. This would have to include general features of ballast piles as well as the characteristics and sources of the stones. The characteristics of the stones include their composition, any apparently intentional modifications, as well as natural and cultural encrustations including barnacles, coral, or building mortar. Continued field and archival research directed toward ballast could help in answering more general questions such as whether or not sand was actually used as ballast aboard certain ships or how different types of stone were likely treated during various periods.

**Final Comments**

Although the conclusions reached in this thesis regarding the uncertainties associated with studying ballast were much the same as those of William Lamb’s thesis (1988:70-72), what was lacking in his approach, and those of other smaller studies, was a thorough explanation of how the features he looked for would have arisen. As with the study of any artifact type, an effort must be made to thoroughly understand the variables and practices which determine and influence the manner in which stone was used during a given period. The absence of such a framework surrounding ballast made designing this thesis more difficult and ultimately resulted in a shift in focus from the Emanuel Point shipwrecks to practices and their archaeological implications. While far from complete, the details gathered in this thesis offer future researchers a background on which to base their research, excavations, and conclusions.
The fragmentary nature of the discussions in this thesis regarding practices is a direct result of the incomplete, scattered, and undocumented distribution of historic records. When more records become available to researchers, whether by careful searches through archives or digitization and distribution of the same materials, the gathered knowledge on partially understood topics like ballast recycling and period specific practices will continue to grow. As the available information and understanding of ships and shipwrecks expands, even the simplest and seemingly trivial artifacts, which at one point may have been given little more than the most cursory of examinations, may take on meanings which once seemed inconceivable.
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Yugoyen, Martin de
Appendix A

\(^{40}\text{Ar}^{39}\text{Ar}\) Geochronology Results for Ballast Stones Recovered from Shipwrecks
40Ar/39Ar Geochronology
Results for Ballast Stones
Recovered from Shipwrecks

By
Matt Heizler

MARCH 13, 2013

Prepared for
Matthew Gifford
University of West Florida

NEW MEXICO
GEOCHRONOLOGICAL RESEARCH LABORATORY
(NMGRL)

CO-DIRECTORS
DR. MATTHEW T. HEIZLER
DR. WILLIAM C. McINTOSH

LABORATORY TECHNICIAN
LISA PETERS

Internal Report #: NMGRL-IR-783
Introduction

Matthew Gifford from the University of West Florida submitted 4 basalt samples to the NMGRL for $^{40}$Ar/$^{39}$Ar dating. The samples are stone ballast balls recovered from shipwrecks Emanuel Point I and II that sank in a hurricane ca. 1559. Dating of the stone ballast is to learn more about maritime interactions and possibly the movements of the vessels before they were part of the Spanish colonization fleet.

$^{40}$Ar/$^{39}$Ar Analytical Methods and Results

Groundmass concentrates were prepared from the 4 basaltic samples by crushing and choosing fragments visibly free of phenocrysts. The prepared samples were irradiated for 10 hours at the UGGS TRIGA reactor in Denver, CO along with the standard Fish Canyon tuff sanidine as a neutron flux monitor. Groundmass was analyzed by the step-heating method using a defocused diode laser to heat the samples (Tables 1, 2). A summary of the preferred eruption ages along with a listing of the analytical methods is provided in Table 1 and the general operational details for the NMGRL can be found at internet site http://geoinfo.nmt.edu/publications/openfile/argon/home/html.

The samples were incrementally heated using between 11 and 13 steps and the age spectra reveal 3 samples with plateau and/or isochron ages between ~7.1 and 7.4 Ma and one sample with a total gas age (TGA) of ~1040 Ma (Table 1, 2; Figs. 1-3). The ca. 7 Ma samples have similar age spectra and overall record apparent ages that decrease across the spectra with the flattest part given by the last 60-80% $^{39}$Ar released (Fig. 1). Isochron analysis demonstrates that some of the age spectra discordance maybe explained by trapped excess $^{40}$Ar (Fig. 3) and thus the isochron age is the preferred age for each of these samples. Sample 94-7L has a disturbed spectrum with most apparent ages scattering between 950 and 1050 Ma (Fig. 2). The disturbed pattern does not allow plateau age calculation and isochron analysis (not shown) does not yield useful information to aid in the age interpretation.
Discussion

The isochron ages for samples 11w3447, 11w3440, and 10w2883 are considered accurate eruption ages for these basalts. 11w3440 and 10w2883 have statistically equal ages at 7.113±0.048 and 7.183±0.052 Ma, respectively. Sample 11w3447 is slightly older at 7.429±0.028 Ma, however this minor difference in age between the samples is unlikely relevant to the overall goals of this study. It is difficult to determine the cause of the age spectrum complexity for sample 94-97L without geological context. It could be caused by alteration or perhaps a complex thermal history following eruption. The total gas age of 1041 Ma is suggested as a possible eruption age and this sample and it is clearly distinct in age compared to the 3 Miocene basalts.

References Cited


Figure 1. Age, K/Ca and radiogenic yield spectra for late Miocene basaltic samples. Each spectra have an overall age decreasing pattern that is likely caused by excess $^{40}$Ar. All isochron ages are interpreted to record accurate eruption ages.
Figure 2. Age, K/Ca and radiogenic yield spectra for basaltic sample 94-97L. Spectrum complexity does not allow for a plateau calculation, however integrated age suggests that sample is approximately 1040 Ma.
Figure 3. Isochron diagrams for Miocene samples.
Table 1. Summary of analytical methods and instrumentation.

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<th>Plateau</th>
<th>Isochron</th>
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<td></td>
<td>Age</td>
<td>%39Ar n</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±</td>
<td>MSWD</td>
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<td>10w2883-001</td>
<td>61225-01</td>
<td>gm</td>
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<td>0.030</td>
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<tr>
<td>94-97L</td>
<td>61224-02</td>
<td>gm</td>
<td>Preferred age = Integrated age 1041±2 Ma</td>
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</tbody>
</table>

L# = Lab number
min = material dated. gm = groundmass concentrate
n = number of steps for plateau or isochron or crystals used for age calculation.
%39Ar = percentage of total 39Ar comprising the plateau or isochron steps.
All errors at 1σ
Age in box is preferred eruption age.

Analytical Methods and Instrumentation

Sample preparation and irradiation:
Groundmass prepared by crushing and hand-picking fragments devoid of phenocrysts.
Samples were loaded into machined Al discs and irradiated for 10 hours, USGS TRIGA Reactor, Denver, CO
Neutron flux monitor Fish Canyon Tuff sanidine (FC-2). Assigned age = 28.02 Ma (Renne et al., 1998)

Instrumentation:
Thermo-Fisher Scientific ARGUS VI mass spectrometer on line with automated all-metal extraction system.
System = Obama
Multi-collector configuration: 40Ar-H1, 39Ar-Ax, 38Ar-L1, 37Ar-L2, 36Ar-L3
Amplification: H1, AX, L1, L2 all 1E12 ohm Faraday, L3 - CDD ion counter, deadtime 14 nS.
Laser Step-heating:
Samples step-heated with 75W Photon-Machines 810 nm diode laser
Reactive gases removed by 8 min reaction with 2 SAES GP-50 getters; 1 at 450°C, 1 at 20°C.
Gas also exposed to cold finger operated at -140°C and a W filament operated at ~2000°C.

Analytical parameters:
Mass spectrometer sensitivity = 1E-16 mol/fA
Total system blank and background: 75±4%, 1.4±62%, 0.50±80%, 0.50±65%, 0.27±0.3%·x 10^-17 moles for masses 40, 39, 38, 37, 36, respectively.
J-factors determined to a precision of ±0.01% by CO2 laser-fusion of 6 single crystals from each of 6 radial positions around the irradiation tray.
Correction factors for interfering nuclear reactions were determined using K-glass and CaF2, and are as follows:
(39Ar/36Ar)K = 0.008236±0.00013; (39Ar/37Ar)Ca = 0.000273±0.000002; and (36Ar/37Ar)Ca = 0.000698±0.000078.
Table 2. Argon isotopic data and age results.

| ID    | Power (Watts) | $^{40}\text{Ar}^{36}\text{Ar}$ (x 10$^{-3}$) | $^{37}\text{Ar}^{36}\text{Ar}$ (x 10$^{-16}$ mol) | $^{36}\text{Ar}^{39}\text{Ar}$ (x 10$^{-15}$ mol) | $^{36}\text{Ar}$ (Ma) | K/Ca (%) | $^{40}\text{Ar}^{39}\text{Ar}$ (Ma) | $^{39}\text{Ar}$ (Ma) | Age ±1σ (Ma) |
|-------|--------------|---------------------------------|---------------------------------|---------------------------------|--------------------|--------|---------------------------------|--------------------|----------------|----------------|
| Xi A  | 17.5         | 5.311                           | 0.5679                          | 12.36                           | 3.98               | 0.90   | 32.0                            | 4.9                | 7.289 ± 0.077 |
| Xi B  | 18.0         | 3.012                           | 0.4025                          | 3.977                           | 15.46              | 1.3    | 62.0                            | 24.2               | 7.990 ± 0.021 |
| X C   | 18.5         | 2.268                           | 0.5090                          | 1.389                           | 10.93              | 1.0    | 77.8                            | 37.8               | 7.547 ± 0.024 |
| D     | 19.0         | 2.197                           | 0.7177                          | 1.798                           | 4.13               | 0.71   | 78.4                            | 42.9               | 7.364 ± 0.055 |
| E     | 19.5         | 2.068                           | 0.7601                          | 1.377                           | 5.64               | 0.67   | 83.2                            | 50.0               | 7.360 ± 0.041 |
| F     | 20.0         | 2.940                           | 0.9588                          | 4.288                           | 13.47              | 0.53   | 59.4                            | 66.7               | 7.482 ± 0.026 |
| G     | 20.5         | 3.240                           | 1.952                           | 5.603                           | 11.39              | 0.26   | 53.7                            | 80.9               | 7.451 ± 0.033 |
| H     | 22.0         | 3.233                           | 7.893                           | 7.143                           | 8.80               | 0.065  | 54.3                            | 91.9               | 7.555 ± 0.041 |
| I     | 26.0         | 3.042                           | 8.370                           | 6.616                           | 2.47               | 0.061  | 57.8                            | 95.0               | 7.57 ± 0.11   |
| X J   | 30.0         | 3.748                           | 9.138                           | 8.972                           | 1.814              | 0.056  | 48.8                            | 97.2               | 7.89 ± 0.14   |
| X K   | 40.0         | 5.459                           | 15.13                           | 16.41                           | 2.10               | 0.034  | 33.5                            | 99.8               | 7.91 ± 0.14   |
| X L   | 60.0         | 14.63                           | 10.96                           | 45.38                           | 0.133              | 0.047  | 14.4                            | 100.0              | 9.1 ± 1.8     |

Integrated age ± 1σ:
- Xi: n=12, 80.3 Ma (K2O=2.60%)
- X: n=10, 45.9 Ma (MSWD=4.47)
- Xi: n=10, 300.1±1.7 Ma (MSWD=4.47)

Plateau ± 1σ:
- Xi: steps D-I, n=6, MSWD=3.24
- Xi: steps C-L, n=10, MSWD=4.47
- Xi: steps B-K, n=10, MSWD=1.66

Integrated age ± 1σ:
- Xi: n=11, 52.1 Ma (K2O=1.39%)
- Xi: steps D-K, n=8, MSWD=0.30
- Xi: steps B-K, n=10, MSWD=1.66

Plateau ± 1σ:
- Xi: steps C-L, n=10, MSWD=15.70
- Xi: steps D-L, n=9, MSWD=11.45
Table 2. Argon isotopic data and age results.

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<tr>
<th>ID</th>
<th>Power (Watts)</th>
<th>(^{40}\text{Ar}/^{39}\text{Ar}) ((\times 10^{-3}))</th>
<th>(^{37}\text{Ar}/^{39}\text{Ar})</th>
<th>(^{36}\text{Ar}/^{39}\text{Ar}) ((\times 10^{-16} \text{ mol}))</th>
<th>(^{40}\text{Ar}^*)</th>
<th>(^{39}\text{Ar})</th>
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**Notes:**
- Isotopic ratios corrected for blank, radioactive decay, and IC, not corrected for interfering reactions.
- Errors quoted for individual analyses include analytical error only, without interfering reaction or J uncertainties.
- Integrated age calculated by summing isotopic measurements of all steps.
- Integrated age error calculated by quadratically combining errors of isotopic measurements of all steps.
- Plateau age is inverse-variance-weighted mean of selected steps.
- Plateau age error is inverse-variance-weighted mean error (Taylor, 1982) times root MSWD where MSWD>1.
- Plateau error is weighted error of Taylor (1982).
- Decay constants and isotopic abundances after Steiger and Jäger (1977).
- X preceding sample ID denotes analyses excluded from plateau age calculations.
- i preceding sample ID denotes analyses excluded from isochron age calculations.
- Weight percent K\(_2\)O calculated from \(^{39}\text{Ar}\) signal, sample weight, and instrument sensitivity.
- Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.02 Ma
- Decay Constant (\(\text{Lambda}_K\) (total)) = 5.543e-10/a
- IC = Measured (\(^{40}\text{Ar}/^{36}\text{Ar}\))/295.5
- Correction factors:
  - \((^{40}\text{Ar}/^{39}\text{Ar})_{Ca}=0.000698 \pm 8e-06\)
  - \((^{40}\text{Ar}/^{36}\text{Ar})_{Ca}=0.000273 \pm 2e-7\)
  - \((^{39}\text{Ar}/^{39}\text{Ar})_{Ca}=0.000236 \pm 0.00013\)
Appendix B

Distribution of Rock Types Within Unit 91N 492E
### Distribution of Rock Types Within Unit 91N 492E

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<th>Rock Type</th>
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Appendix C

Thin-sections from Wagner Petrographic
Thin-section of sample 94-97L. Image courtesy of Dr. Chris Kelson of SUNY Potsdam.
Thin-section of sample 10W2883-001. Image courtesy of Dr. Chris Kelson of SUNY Potsdam.
Thin-section of sample 11W3440-001. Image courtesy of Dr. Chris Kelson of SUNY Potsdam.
Thin-section of sample 11W3447-001. Image courtesy of Dr. Chris Kelson of SUNY Potsdam.
Appendix D

Geochemical Data from Analysis by ALS Minerals
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Geochemical Data from Analysis by ALS Minerals continued

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