Geoarchaeological Investigations at a Stege Mound (CA-CCO-297), a Late Period Shellmound: A Study of Archaeological Site Formation and Paleoenvironment Reconstruction along the San Francisco Bay Estuary, California

by

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30 April 2015
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Abstract

Purpose of the Study: This thesis investigates the influence of paleoenvironmental conditions on prehistoric cultural occupation at CA-CCO-297, a Late Period Ohlone village site. A recent cultural resource management project conducted at the site made it possible to research CCO-297’s cultural and natural deposits that were extracted from column and core samples. The purpose of this thesis is to examine those sediments for evidence of a cultural response to environmental change along the San Francisco Bay estuary.

Methods: This study incorporates archival research with field-based and laboratory techniques. Field-based techniques include the excavation, recording, and interpreting of stratigraphic profiles, and the collection of column and core samples for laboratory analysis. Laboratory techniques conducted on the samples include loss on ignition, magnetic susceptibility, phosphorus, potential of hydrogen, macrofossil and microfossil analysis. The combination of archival research, fieldwork, and accompanying laboratory procedures produces data sets useful for the paleoenvironment reconstruction and reveal natural site formation processes.

Findings: Site CCO-297 is situated on a terrestrial landform on the edge of a tidal creek during the site’s initial occupation in 1350 cal AD. A reconstruction of the paleoenvironment reveals that a tidally influenced brackish marsh was at its peak in evolution shortly before occupation of the site began, with the peak of the marsh occurring soon after 1203 cal AD. The marsh was initially formed by a strictly freshwater inflow. The peak of the marsh’s formation and the initial occupation of the site closely coincide with the transition of the Medieval Climatic Anomaly (MCA) to the Little Ice Age (LIA) that is estimated to have occurred from 1350 to 1450 cal AD.

Conclusions: Formation of prehistoric shellmound site CCO-297 directly correlates with the dynamic evolution of a tidally influenced brackish marsh along the San Francisco Bay estuary during the late Holocene. The results of this research place CCO-297 into the context of an evolving paleo-landform, one that was affected by shifting climatic periods from the MCA to the LIA. This thesis shows how environmental factors influenced archaeological site formation processes during the Late Period along the San Francisco Bay estuary.
Chair: Adrian Praetzellis, Ph.D.

MA Program: Cultural Resources Management
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Chapter 1. Introduction

In this thesis I provide evidence on natural and cultural site formation processes at a Stege Mound (CA-CCO-297), a prehistoric shellmound, and its relation to changes in the paleoenvironment along the San Francisco Bay estuary during the middle and late Holocene. Recent excavations at Contra Costa 297 (CCO-297) produced radiocarbon, obsidian hydration, and temporally discrete items that place human occupation at CCO-297 occurring from approximately 1350 to 1770 cal AD (DeGeorgey 2015). The occupation period comes after a shift in climate known as the Medieval Climatic Anomaly (MCA) and during a period established as the Little Ice Age (LIA). Soil and sediment samples collected at CCO-297 for this study made it possible to investigate the dynamic elements of past environmental changes that are contained within the site’s natural and cultural deposits. Changes in the natural environment appear to have influenced both the timing and physical location of prehistoric settlement at Stege.

Research Objective

This thesis uses geoarchaeological data taken from CCO-297 to address the research question: how did middle and late Holocene environmental factors affect human occupation and site formation at CCO-297? Answering this question is accomplished by establishing; (1) the temporal context, (2) the spatial context, (3) the paleoenvironmental context, and (4) the prehistoric cultural context of CCO-297. The use of geoarchaeological concepts and techniques that stem from earth sciences such as geomorphology, paleoecology, sedimentology, pedology, and stratigraphy, aid in
recreating natural site formation processes of the dynamic landscape environment, and place CCO-297 into a framework of a “complete human ecosystem” (Waters 1992:13). Establishing natural site formation processes is important because an understanding of the environmental context allows for a better interpretation of culture and cultural change (Rapp and Hill 2006:274). Additionally, this geoarchaeological approach is important to archaeology because prehistoric settlement patterns during the middle and late Holocene around the Bay Area is theorized to be a cultural response to environmental factors such as the MCA and periods of cooler-wetter conditions (Bickel 1978; Wiberg 1996; 1997; Meyer and Rosenthal 1997; Ingram 1998).

The MCA occurred from about 800 to 1350 cal AD (Stine 1994; Jones and Klar 2007; Schwitalla 2013), and is a period that increased atmospheric temperature in certain global regions. California is characterized as having experienced unusually dry periods and drought conditions during this period. The LIA occurred from about 1450 to 1800 cal AD (Malamud-Roam et al. 2006:1570, 1593), and is associated with cooler climates and wetter conditions. Evidence for both climatic changes has been found in sediments throughout the San Francisco Bay Area (Goman and Wells 2000; Malamud-Roam et al. 2006; Goman et al. 2008; McGann 2008). The MCA occurred during a cultural sequence known as the Late Period and Augustine Pattern in the San Francisco Bay Area. This period is associated with increased social stratification, new tool technology, and a change in mortuary practices and exchange systems (Milliken et al. 2009; Arnold and Walsh 2010). This period is also associated with cultural abandonment or sporadic use of
bay-shore shellmounds (Ingram 1998; Lightfoot and Luby 2002; Arnold and Walsh 2010).

This thesis uses existing maps, satellite images, and data retrieved from column and core samples, integrated with an analysis of radiocarbon dates, to address the research question concerning environmental factors and their influence on prehistoric site formation. Testing of soil and sediment samples retrieved from CCO-297 revealed information on past environmental conditions, formation, and deposition that occurred before and during prehistoric occupation at CCO-297. The laboratory techniques in this study are approaches to stratigraphy and landform reconstruction currently used in geoarchaeological investigations (Goldberg and Macphail 2006; Rapp and Hill 2006; Jones 2007). This includes loss of ignition (LOI), potential of hydrogen (pH), magnetic susceptibility (MS), phosphate testing, macrofossil and microfossil analysis. Interpretation of this data allows the examination of natural site formation processes and advances our understanding of how those processes affected the context of the site and archaeological record.

Relevance to Cultural Resources Management

The San Francisco Bay Area can be a challenging place to conduct archaeological research due to the vast and daunting amount of data available for interpretation. Data resides in published reports, unpublished notes, gray literature, and archived collections in museums and storage facilities (Arnold and Walsh 2010:75). Fortunately, this region enjoys a classic blending of academic interest and Cultural Resource Management
(CRM) enterprises (Luby et al. 2006). Prehistoric investigations on shellmound sites have been a focus for both CRM practitioners and academia archaeologists and has resulted in intensive studies “that may be unmatched anywhere in California” (Arnold and Walsh 2010:75). These cultural resources once numbered in the hundreds along the landscape. During the first decade of the 19th century, Nels Nelson recorded at least 425 mounded sites along the Bay Area, noting that “not a single mound of any size is left in its absolutely pristine condition” (1909:327). Urban expansion and development had destroyed most of the shellmounds since Nelson’s original recordings (Luby et al. 2006:191; Arnold and Walsh 2010:65).

Modern development is still affecting these mounds, as apparent from the Marina Bay Parkway Grade Separation Project from which data for this thesis were developed. An analysis of the prehistoric natural environment is important because “before archaeologists can infer meaningful interpretations of human behavior from existing context, they must know how it was created” (Waters 1992:11). By this reasoning, the need to understand the archeological context goes beyond the material analysis of artifacts. Currently, earth-science components are increasingly required as part of CRM investigations in the United States. Additionally, geoarchaeological analyses of landform elements are frequently being used in archaeological investigations and the development of cultural resource management and evaluation strategies (Rapp and Hill 2006:270).
Figure 1. Study area (DeGeorgey 2013).
Study Area

Site CCO-297 is a prehistoric shellmound located in the City of Richmond on the northeast side of San Francisco Bay, in western Contra Costa County, California (Figure 1). This area is at the southern edge of a broad, generally flat alluvial plain and along the southeastern margins of a formerly extensive expanse of salt marsh present along the San Francisco shore (DeGeorgey 2013:7). The Southern Pacific Railroad and the northwest corner of the PG&E Richmond Service Center equipment yard form the northeast perimeter of the site.

The Marina Bay Parkway Grade Separation Project

This thesis uses data from CCO-297 that was taken during the 2014 cultural resource investigation for the Marina Bay Parkway Grade Separation Project. In 2010, work began at the Marina Bay Parkway railroad crossing in Richmond, California. The Marina Bay Parkway Grade Separation Project, also known as the Officer Bradley A. Moody Memorial Underpass, is an estimated $37.5 million project with redevelopment funding from the California Department of Finance (DOF) that includes: a grant from the California Transportation Commission; Successor Agency to the Richmond Community Redevelopment Agency; Proposition 1B Trade Corridor Improvement Fund (TCIF); Contra Costa Transportation Authority; Metropolitan Transportation Commission; Measure J transportation sales tax, developer fees; and the Union Pacific Railroad (UPPR) (City of Richmond 2013; Rogers 2013; Smalley 2013; Smalley 2015). The project consists of a 365.7 m depressed roadway that requires approximately 7.6 m of
subsurface excavation below the existing grade (Smalley 2013). The expected date for
competition is May of 2015 (Smalley 2015). The project is situated within the limits of a
known prehistoric archaeological site (CCO-297) and an archeological district known as
the Stege Mounds (DeGeorgey 2013:1).

**Regulatory Background**

An understanding of the regulatory context that pertains to cultural resources is
necessary when conducting CRM investigations. For this reason, and the fact that this
thesis research is for a Master of Arts degree in CRM, a regulatory background of the
Marina Bay Parkway Grade Separation Project and archaeological site CCO-297 is
provided. The Stege Mounds have been determined eligible for inclusion into the
National Register of Historic Places (NRHP) under Criterion D for their potential to yield
information important to prehistory as an archeological district (Banks and Orlins
1981:1.4). The NRHP is the federal government’s official list of “historic places worthy
of preservation” and is maintained by the National Park Service’s National Register
division (King 2013: 85; NPS 2013). The NRHP was established by the National
Historic Preservation Act of 1966 (NHPA). Properties that are eligible for inclusion on
the NRHP must meet the listing criteria at 36 CFR 60.4 (Hardesty and Little 2009:12;
King 2013:86). The Stege Mounds, and any sites determined eligible for the NRHP, are
automatically considered eligible for the California Register of Historical Resources
(CRHR) (PRC § 5024.1, 14 CCR § 4850). The California Register is described as “an
authoritative guide to the states historical resources and to which properties are considered significant for purposes of CEQA” (CA OHP 2002).

The Richmond Community Redevelopment Agency, acting as the lead agency for the Marina Bay Parkway Grade Separation Project, addressed the California Environmental Quality Act (CEQA) and its regulations found in the CEQA Guidelines, codified in Title 14 of the California Code of Regulations, as part of the compliance process (City of Richmond 2013; DeGeorgey 2013). Under CEQA, cultural resources must be evaluated to determine if they are historical resources and their eligibility or listing in the CRHR as defined in Section 5020.1(a) of the California Resources Code. The resource designated CCO-297 had been found eligible for listing on the CRHR due to its eligibility to the NRHP. If any other archaeological resources were to be determined ineligible for listing on the CRHR – unless it is considered a unique archaeological resource as outlined in the CEQA (PRC Section 21083.2) – it would be released from management responsibilities, and the project could proceed without further cultural resource considerations. According to Section 5024.1(c) of the California Public Resources Code, a cultural resource “may be listed as an historical resource in the California Register if it meets any of the following National Register of Historic Places criteria.” These criteria include: (1) is associated with events that have made a significant contribution to the broad patterns of California’s history and cultural heritage; (2) is associated with the lives of persons important to our past; (3) embodies the distinctive characteristics of a type, period, region, or method of construction, or represents the work
of an important creative individual, or possess high artistic value; and (4) has yielded, or is likely to yield, information important to prehistory or history.

However, given the scope of development proposed for the Marina Bay Parkway Grade Separation Project, it was deemed statutory exempt from CEQA making it a ministerial project not subject to CEQA requirements, even though the project has the potential to significantly affect cultural resources. The reason for the exemption status, as determined by the California State Legislature, has to do with the railroad grade separation aspect of the project. Under CEQA Guidelines Article 18, Section 15282 (g), the Public Resources Code section 21080.13 provides that CEQA shall not apply to “any railroad grade separation project which eliminates an existing grade crossing or which reconstructs an existing grade separation.” As the project was deemed exempt from CEQA, a Notice of Exemption (NOE) was filed by The City of Richmond Community Redevelopment Agency and sent to the State Office of Planning and Research (OPR) as outlined in 14 CCR Section 15062(c1) (CNRA 2007a).

In addition to complying with the CEQA process, The City of Richmond’s Community Redevelopment Agency also complied with the requirements of the Historic Structures Code (Chapter 6.02 of the Municipal Code) of the City of Richmond, as amended (DeGeorgey 2013:1). The purpose of the City of Richmond’s Historic Structures Code (Chapter 6.06) is to:

Promote the general welfare by providing the identification, protection, enhancement, perpetuation, and use of improvements, buildings, structures, signs, features, sites, places, and area within the City that reflect special elements of the City’s historical, architectural, archaeological, cultural, or aesthetic heritage.” (City of Richmond 2000).
Section 6.06.030.18 of the Historic Structures Code defines a “Richmond Historic Landmark” to mean “one or more buildings or structures or sites having significant historic or architectural work” and “is deemed to be so important to the historical and architectural fabric of the city that its loss would be a major loss to the City” (City of Richmond 2000). Additionally, § 6.06.030.18 (I) of the code defines the Stege Mounds Archeological District as a “Richmond Historic Landmark.” Section 6.06.070 (a) states “no exterior addition, alteration, or demolition shall be made by any person to a historic resource without review and approval by the Design Review Board or appeal by the Council.” Furthermore, § 6.06.080 provides enforcement and penalties stating that it is a misdemeanor to violate any of these requirements, and civil action “shall be in addition to, and not in lieu of, any criminal prosecution and the penalty or other remedy provided by law” (City of Richmond 2000).

In meeting the cultural resource management requirements established under the City of Richmond’s Historic Structures Code (Chapter 6.06) and the CEQA, a research design and treatment plan was developed to mitigate potential adverse effects to the resources through implementation of data recovery through excavations, similar to guidelines stated in Section 15126.4 (B)(C) of CEQA (CRNA 2007b). The mitigation of effects to significant prehistoric properties included four components such as the development of a treatment plan, field excavations, laboratory analysis, and report preparation (DeGeorgey 2013:5). In 2013, Alta Archaeological Consulting was contracted to develop a research design, data recovery program, and work plan to mitigate the impacts on the cultural resources (CCO-297). A Treatment Plan for the
project was approved by the City of Richmond’s Historic Resources Commission and the Design Review Board, pursuant to §6.06.70(a) of Richmond’s Historic Structure Code (Chapter 6.06) (City of Richmond 2000; DeGeorgey 2013).

Richmond’s local government codes for the management of their historical resources, and the preservation and protection provided by them, allows the mitigation of potential effects on cultural resources that is not required under the CEQA Guidelines, as the project is statutory exempt. The enforcement and penalties provided by the City of Richmond’s Historic Structures Code (Chapter 6.06) to protect the Stege Mounds Archeological District include a misdemeanor offence for any person found in violation of Chapter 6.06. It also allows for civil action against anyone found in violation of the Historic Structures Code.

**Organization of Thesis**

This thesis is designed to provide the natural and cultural background related to the San Francisco Bay and discuss the methods and findings of my research that emphasize the link between environmental change and cultural response. Chapter 2 provides theoretical framework and important background information on the geoarchaeological approaches used in this study. Chapter 3, 4, and 5 give relevant background information on the environment and cultural contexts of the research area. Chapter 6 describes the methods used in this study followed by the results and interpretations, in Chapter 7. The final chapter, Chapter 8, is where I summarize site
formation processes in relation to a reconstructed paleoenvironment, and their correlation to environmental change along the San Francisco Bay estuary.
Chapter 2. Geoarchaeological Approach

Introduction

“Since archaeology, or at least prehistoric archaeology, recovers almost all its basic data by excavation, every archaeological problem starts as a problem in geoarchaeology” (Renfrew 1976:2). This quote by Renfrew defines the basic premise why geoarchaeological research is needed when conducting archaeological investigations. Geoarchaeology is the application of concepts and methods used in earth sciences, or geosciences, to interpret or solve archaeological questions (Pollard 1999:7; Rapp and Hill 2006:1; Jones 2007:2). Specifically, geoarchaeology uses methods and techniques that stem from geomorphology, paleoecology, sedimentology, pedology, stratigraphy, and geochronology to investigate sediments, soils, and landforms at archaeological sites (Waters 1992:4).

The methods offered in geoarchaeology help solve archaeological context problems. Butzer (1982:4) defines context as the “four dimensional spatial-temporal matrix that comprises both a cultural and non-cultural environment and that can be applied to a single artifact or to a constellation of sites.” There are three broad approaches used by geoarchaeologists to address research questions concerning archaeological contexts. These include: (1) the temporal context of the site (stratigraphy and geochronology); (2) the spatial context and preservation of material on site and between sites (natural site formation processes); and (3) the prehistoric landscape context of the site (Waters 1992:12).
The first research objective described above, estimating the age of cultural stratigraphic deposits, is commonly practiced in archaeology by using absolute dating techniques such as radiocarbon testing. The geoarchaeologist’s role is to evaluate the stratigraphy, sediments, and post depositional history from where the archaeological sample was taken to make sure no mixing or contamination skews the archaeological context (Waters 1992:9).

The second research objective, understanding the natural processes of site formation, incorporates understanding the physical, chemical, and biological factors that are responsible for the burial, alteration, and destruction of the systemic context of the site (Waters 1992:11). Systemic context, defined by Schiffer (1972:157), “labels the condition of an element which is participating in a behavioral system.” All materials that compose a cultural system (e.g., foods, tools, human beings, etc.) are defined as elements that participate in the behavioral system. The systemic context is a fundamental aspect of archaeology and includes researching human behavior patterns beyond the analysis of a single site, by studying a group of related sites, thus allowing the reconstruction of human behavior at a regional scale. The study of natural site formation at a regional scale aids in determining if the archaeological sites in a region are representative of the “type and density of the sites that once existed in that area at a particular time and through time” (Waters 1992:11).

The third research goal, reconstructing the landscape that was present during the site’s occupation, allows for a holistic interpretation of past human behavior as it establishes the environment that people once lived in. The reconstruction is made by
analyzing the ecofacts of the past environment that includes plant macrofossils, pollen, phytoliths, and faunal remains (Waters 1992:11; Rapp and Hill 2006:169-182). As the environment is always changing, these ecofacts are evidence of landscape evolution, and identifying these ecofacts can explain cultural change. This makes it essential to reconstruct the physical landscape of the site before, during, and after its occupation (Waters 1992:12).

Investigating archaeological sites with the aid of these three research goals puts the study into a cultural, biological, climatic, and landscape context, formulating what is described as a “complete human ecosystem” (Waters 1992:13).

**History and Theory**

The roots of geoarchaeology lie in the 19th century during a time when the scientific fields of archaeology and geology both focused on evidence concerning early human occupation in North America and Europe (Pollard 1999:7-8; Rapp and Hill 2006:4). At this time, geologists debated the arrival of the first humans who came to Europe by analyzing the stratigraphy of early sites and estimating their age (Waters 1992:7). In 1858, Sir Charles Lyell, regarded as one of the founders of modern geology and geoarchaeology, supervised the excavation of prehistoric human remains and their artifacts at Brixham Cave in England (Rapp and Hill 2006:6). Methods used in the excavation included documenting the stratigraphy and the deposits in an uniformitarian geologic context. This lead to the conclusion that humans were alive and inhabited the area during the Ice Age (Rapp and Hill 2006:6), and that the deposits were not what was
popularly believed to be as biblical remnants of Noah’s Great Flood, or from the earth’s biblical creation in 4004 BC according to James Ussher (Pollard 1999:8).

Lyell’s work established the principle of uniformitarianism in geology (Pollard 1999:8; Rapp and Hill 2006:6). This is a system of assumptions that views that the Earth surface processes can be explained in three uniformities (process, rate, and state), as well as the unity of law – a premise for all scientific work that states natural laws (e.g., physics, chemistry, and biology) operating in the present have operated similarly in the past (Huggett 2007:17). Uniformitarianism is a fundamental component in geoarchaeology that provides a basis for understanding the nature of past processes.

The second half of the 19th century marked a period when an increased number of archaeologists from North America and Europe began using stratigraphic methods to observe and interpret cultural deposits. From 1900 to 1950, the field of geoarchaeology experienced a refinement of field methods and an increase in the collaboration between archaeologists and geoscience specialists. Rapp and Hill (2006:10) refer to this period as a collaborative phase in the history of geoarchaeology. Geoarchaeologists in this period expanded their studies to include paleoenvironment and paleoclimatic changes, as well as chronology. The focus on chronology shifted in the 1950s with the development of radiocarbon dating by Willard Frank Libby in the late 1940s (Rapp and Hill 2006:16).

The 1950s to the present is characterized by new interactions of methods between earth sciences and archaeology, and the development of theoretical basis for archaeological studies (Rapp and Hill 2006:17). Two subphases in the development of theoretical framework include the acknowledgment of the potential role of geoscientists
in archaeology that occurred during the 1940s and 1950s, and then more “formal statements from the 1960s through the early 2000s” (Rapp and Hill 2006:17).

In the 1960s, some archaeologists viewed that the archaeological record could not be directly used to observe human behavior, but suggested it could infer the past processes that created it. These concepts formed the theoretical developments of processual archaeology. It was during this time that Michael B. Schiffer (1972:157) differentiated between the “archaeological context” and the “systemic context”. While the systemic context “labels the condition of an element participating in a behavioral system”, the archaeological context “describes material which has passed through a cultural system, and which are now the objects of investigation by archaeologists” (Schiffer 1972:157). Schiffer (1972:158) divided the systemic context into five processes: procurement, manufacture, use, maintenance, and discard.

One of the implications of systemic context is that it focuses on identifying the processes that created the archaeological record (Rapp and Hill 2006:19). The most important notion of systemic context is that the processes take place in specific locations, and the locations are places where the probability of finding an element is high (Schiffer 1972:160; Stein 2001b:40). Michael Schiffer’s contributions and influence to the field of geoarchaeology is fundamental, and is described by Stein (2001a:8):

Schiffer (1972, 1983, 1987) propelled the study of geoarchaeology to the forefront of the discipline by suggesting emphatically that archaeologists must interpret the deposits from which their artifacts came. He did, however, emphasize the difference between natural formation processes (n-transforms) and cultural formation processes (c-transforms), which has continued to influence archaeologists ever since.
Geoarchaeology first became a recognized specialty with the appearance of the edited volume “Geoarchaeology: Earth Science and the Past” by Davidson and Shackley in 1976, where Renfrew (1976) coined the term “geoarchaeology” in the volume’s preface (Stein 2001b; Goldberg and Macphail 2006). Renfrew defined geoarchaeology as a discipline that is “primarily concerned with the context in which archaeological remains are found” by employing the skills of geological scientists (Renfrew 1976:2). Renfrew’s 1976 definition of the term indicated there was “an increase awareness of the need for interdisciplinary cooperation between archaeologists and earth scientists” (Stein 2001b:43).

The theoretical concepts that developed from post-processual theory in the 1980s and 1990s cemented the importance of using natural science perspectives in archaeology. It is now professionally acknowledged that “archaeological data appear as the product of varying proportions of human behavioral activities and natural geologic processes” (Rapp and Hill 2006:19-20). Thus, studying the processes that created the archaeological record should include documenting and evaluating the paleoenvironmental context.

A transitional phase in the field of geoarchaeology is underway in the 21st century. Rapp and Hill (2006) explain there were no graduate programs in the United States dedicated to educating geoarchaeologists prior to the mid-1970s. This meant the majority of geoarchaeologists came from the earth science departments, as opposed from anthropology or archaeology. This trend has changed in North America in the 21st century as those educated in geoarchaeology now come from anthropology and archaeology departments. Along with the increased recognition in the academic
community for the value of geoarchaeology, the expansion of techniques used in its application is a sign that the field is still maturing (Rapp and Hill 2006:22-23).

Geoarchaeological Concepts and Foundations

This section defines important geoarchaeological concepts and foundations that are currently applied in the science. Five major concepts discussed include the principles of both sedimentation and stratigraphy, soil formation processes, site formation processes, and landscape reconstruction. The discussed concepts and foundations provide a framework for the geoarchaeological approaches used in this study.

Principles of Sedimentation

The process of interpreting layers in an archaeological context must begin by understanding the terms used in describing deposition. First, another term for layer is “deposit,” and can be defined in the field on the basis of any observable change such as color, artifact content, soil chemistry, organic percentage, or any physical properties (Stein 2001a:4). The definitions of sediments are “particulate matter that has been transported by some process from one location to another” (Reineck and Singh 1980; Stein 1987:339). This broad definition implies: (1) sediments are made from anything composed of mineral or organic material; (2) the particle has been transported; (3) the sediment can be grouped into a deposit; (4) the rate of transport and deposition is not specified, and; (5) the process of transport can be natural or cultural (Stein 2001a:7-8).

According to the principles of sedimentation, an archaeological investigation of layers requires an interpretation of the depositional history for all sediments in each
deposit (Stein 2001a:9). The principles of sedimentation contain four stages that comprise the sediment’s history: (1) source, (2) transport agent, (3) environmental deposition, and (4) post-depositional alteration (Stein 2001a:10). Stages 1 through 3 consist of the sediment’s depositional history, while stage 4 occurs after deposition takes place (e.g., bioturbation or chemical alterations). The most important post-deposition alteration in archaeological context is weathering (Stein 2001a:16), and is defined by physical and chemical alteration of rock and minerals near the earth’s surface (Birkeland 1999:53).

Sediments consist of three main groups; clastic deposits, chemical deposition, and organic matter. Clastic deposits contain fragments of particles derived from existing rocks, and the size of those particles can be described by its texture (Rapp and Hill 2006:29), and often make up the most significant portion of the archaeological matrix (Waters 1992:19). These deposits range in size from boulders to pebbles, gravels, sands, silts, and clays (Huggett 2011:68-69). Chemical deposition is the category of sediments consisting of minerals that have been deposited “by precipitation from solution” (Rapp and Hill 2006:35). The most common mineral is calcite (calcium carbonate), and can include, but is not limited to, others such as phosphate, iron oxide, and silica. Organic matter consists of sediments containing decaying or decayed plants and animals. The organic percentage of sediments can be as high as 100%, indicating the sediments originated from freshwater-marsh conditions (Rapp and Hill 2006:37). Sediments that are high in organic matter are called carbonaceous.
Processes of Soil Formation

An understanding of soils is fundamental in archaeology because soils are an essential component in any environmental reconstruction as they can provide evidence of past human activity (Goldberg and Macphail 2006:42). Soil formation is described as a “surficial process during which the upper portion of a sedimentary deposit or rock layer on a stable surface is physically or chemically altered in place” (Waters 1992:41). Five soil-forming factors include: (1) climate, (2) organisms (including humans), (3) relief (topography), (4) parent rock, and (5) time (Jenny 1941). The formation of soils creates a vertical and horizontal distinction that creates a profile displaying the sequences, termed soil horizons, which lie horizontal to one another and parallel with the surface (Waters 1992:45). These horizons “reflect changes in mineralogy, texture, and chemistry usually caused by weathering” (Stein 2001a:18), which together form a soil profile (Jones 2007:11). Horizons can be categorized by using an adaption of the ABCD system of horizon designation (Bridges 1990). Well-developed soil profiles usually contain horizons A, B, and C, from top to bottom (Waters 1992:45).

Soil Types

Identification of certain soil types is important in geoarchaeology as the soils can inform the researcher how to reconstruct past environmental and climatic conditions (Rapp and Hill 2006:41). These soils include: entisols, vertisols, inceprisols, entisols, mollisols, alfisols, ultisols, spodosols, aridosols, and histosols (Rapp and Hill 2006:41). Paleosols are soils that formed in the past but are not undergoing soil formation in the present. Buried paleosols can be evident in the soil stratigraphy, and indicate formally
stable land surfaces or past environmental conditions, and are well represented in archaeological contexts (Rapp and Hill 2006:43). Past environments, such as the presence of marsh conditions and waterlogged areas, can be inferred from the presence of carbonaceous paleosols, such as the presence of peat accumulations (Rapp and Hill 2006:44).

**Stratigraphic Principles**

Stratigraphic principles are fundamental to the study of archaeology as they “define the interfacial relationships between features and deposits of a site” (Harris 1979:112). The four primary stratigraphic laws utilized in the field of archaeology include: (1) superposition, (2) original horizontality, (3) original continuity, and (4) stratigraphical succession. The first three of these laws are adapted from geological sources, while the fourth is an archaeological invention (Harris and Reece 1979). Harris (1979: 112-113) describes the four laws in detail:

**The Law of Superposition:** in a series of layers and interfacial features, as originally created, the upper units of stratification are younger and the lower are older, for each must have been deposited on, or created by the removal of, a pre-existing mass of archaeological stratification.

**The Law of Original Horizontality:** any archaeological layer deposited in an unconsolidated form will tend towards a horizontal deposition. Strata which are found with tilted surfaces were so originally deposited, or lie in conformity with the contours of a pre-existing basin of deposition.

**The Law of Original Continuity:** any archaeological deposit, as originally laid down, will be bounded by a basin of deposition, or will thin down to a feather-edge. Therefore, if any edge of the deposit is exposed in a vertical plane view, a part of its original extent must have been removed by excavation or erosion: its continuity must be sought, or its absence explained.

**The Law of Stratigraphical Succession:** any given unit of archaeological stratification takes its place in the stratigraphic sequence of a site from its position between the undermost of all units which lie above it and the uppermost of all those units which lie below it and with which it has a physical contact, all other superpositional relationships being regarded as redundant.
The basis behind the law of superposition is closely tied to the law of original horizontality. Original horizontality is important in the study of sedimentary rocks and sediments because most form in horizontal layers. The principle of original horizontally is an uniformitarianism perspective, and is associated with the works of Sir Charles Lyell in the 19th century, as previously discussed in this chapter. The law of superposition states that any set of observed strata will have a bottom layer that was deposited before the top, or, the oldest layers are at the bottom and youngest are at the top (Boggs 1995:638). This law is of fundamental importance in recording archaeological sites because it assumes the position of the strata and features encountered resemble their original deposition (Harris 1979:113).

Stratigraphy applies these and other concepts to interpret the evolution and relationship between stratigraphic units. Stratigraphy is defined as “the study of spatial and temporal relationships between sediments and soils and are created by depositional environments that are constantly changing” (Waters 1992:60). Within the sedimentary environments there are three potential conditions occurring at any given time:

(1) Aggradation, when sediments are accumulating; (2) stability, when erosion and deposition are at form of an equilibrium stage and when soil formation occurs; or (3) degradation, when previously deposited sediments and previously formed soils are removed by erosion. One of these conditions dominate the physical environment at any given time. If the environmental conditions change, an interbedded sequence of sediments, soils, and erosional contacts is created (Waters 1992:60).

Three categories of stratigraphic units – lithostratigraphic units, pedostratigraphic units, and chronostratigraphic – represent the most useful geologic stratigraphic unit types applied in archaeology (Waters 1992:62). These units are defined by the North American Stratigraphic Code (NASC), developed by the North American Commission
on Stratigraphic Nomenclature in 1983, and revised in 2005 (NACSN 2005). The following are descriptions of the three stratigraphic units provided within the NASC:

1. A *lithostratigraphic unit* is a stratum or body of strata, generally but not invariably layered, generally but not invariably tabular, that conforms to the Law of Superposition and is distinguished and delimited on the basis of lithic characteristics and stratigraphic position. Example Navajo Sandstone.

2. A *chronostratigraphic unit* is a body of rock established to serve as the material reference for all rocks formed during the same span of time. Example: Devonian System. Each boundary of a chronostratigraphic unit is synchronous. Chronostratigraphy provides a means of organizing strata into units based on their age relations. A chronostratigraphic body also serves as the basis for defining the specific interval of geologic time, or geochronologic unit, represented by the referent.

3. A *pedostratigraphic unit* is a body of rock that consists of one or more pedologic horizons developed in one or more lithic units now buried by a formally defined lithostratigraphic or all stratigraphic unit or units. A pedostratigraphic unit is the part of a buried soil characterized by one or more clearly defined soil horizons containing pedogenically formed materials and organic compounds (NACSN 2005:1157-1158).

**Archaeological Site Formation Processes**

This section will define archaeological site formation processes and then focus on the formation of estuarine environments, specifically wetlands and marshes, as they pertain to the research scope of this thesis. This is followed by a brief summary on the formation processes and deposits of prehistoric shell middens found in coastal environments.

The study of site formation processes is important in geoarchaeological studies because most investigations within the field are concerned with how deposits were initially laid down and modified throughout time (Jones 2007:2). Formation processes are also important because archaeologists need to decipher any natural processes that might have disturbed patterns of artifacts in the ground that are used to infer cultural behavior (Stein 2001b: 37-38).
Schiffer (1987) described the study of formation processes must include an analysis of “transformations” as to identify the systemic and archaeological context. These transformations can be either cultural or natural (noncultural) processes. Schiffer (1987:7) defines natural formation processes as “any and all events and processes of the natural environment that impinge upon artefacts and archaeological deposits.” Cultural formation processes are defined as “the processes of human behavior that affect or transform artifacts after their initial period of use in a given activity” (1987:7). In this sense, the term formation processes “describes research about the transformation of the record, but also describe the original behavior surrounding the artifacts” (Stein 2001b: 41).

The processes of site formation can be interpreted as occurring in two stages. The initial stage produces a primary archaeological deposit. A primary deposit is one that has been deposited from direct human behavior (e.g., human deposition, plowing, trampling, and excavation), were no rearrangement or reconstruction by geologic and biologic forces has occurred (Rapp and Hill 2006:62). This primary deposit is part of the systemic context described by Schiffer (1972:157). The second stage of site formation contains secondary archaeological deposits that have been affected by natural processes, and is called the archaeological context (Schiffer 1972:157). Artifacts modified by redeposition or digenetic processes are characterized as secondary deposits (Rapp and Hill 2006:62).

The same geomorphic processes that have occurred on the landscape throughout time can shape the archaeological record. Archaeological sites on a stable landscape may remain on the surface without becoming buried or blown away. The opposite occurs if
the site is situated, or becomes situated, in an area subject to erosional or depositional conditions (Waters 1992:92). Deposited archeological remains can be preserved by either being buried in the sediments of the lithostratigraphic unit, buried in a pedostratigraphic unit, or they are buried on the contact between a pedostratigraphic and a lithostratigraphic unit (Waters 1992:93).

_Estuaries and Marshes_

Landforms such as tidal flats, tidal marshes, and tidal channels are constructed of fine-grain sediment through tidal action if estuaries and marshes are protected by embayments (Wells 2001:162). Weak tidal currents will deposit mud and clay on shallow flats forming a lower intertidal zone that is occupied by mudflats, and an upper intertidal zone occupied by the salt or brackish marsh (Wells 2001:162). The mudflat sediment is a mixture of silt and clay that contains high iron content and mollusks, while tidal marsh peat is a mixture of very fine-grained clay and silt with high organic content (Wells 2001:162). Low energy estuarine mudflats and lagoonal environments contain a rich collection of archaeological remains. This is due to Holocene sea level rise that buries sites under marine and intertidal muds (Goldberg and Macphail 2006:160).

Progradation of the coastline occurs in areas of high sediment supply and low to moderate costal subsidence, providing conditions that are the best for the possible preservation of archaeological sites (Waters 1992:272). Archaeological sites found on prograding shorelines were likely inhabited due to their proximity to marine resources. Younger sites tend to be established closer to the shore after the progradation has created
new shoreline landforms, making sites found farther inland older than the ones currently closer to shore (Waters 1992:274).

The composition of wetland deposits, including the natural organic remains found in them (e.g., foraminifera, diatoms, plant remains, insects, and pollen), provides a detailed sequential environmental record for the period over which they formed. This environmental record provides a landscape context for human activity and organic material well suited for dating (Jones 2007:8). Wetlands contain very little oxygen because of constant saturation, thus limiting the activity of bacteria, fungi, and soil animals normally responsible for the breakdown of organic material. These conditions result in exceptional states of preservation for archaeological analysis (Jones 2007:8).

Shell Middens

Shell middens are anthropogenic deposits found in coastal areas throughout the world (Goldberg and Macphail 2006:166), and are one of the most stratigraphically complex types of archaeological sites (Stein 1992:XV). Cultural deposits found in middens include shell, gravel, sand, silt, charcoal, artifacts, and other cultural and biological remains that can occur as solitary deposits or in association with architectural sites (Wells 2001:164). When shells accumulate due to human harvesting an extensive deposit might accumulate. The properties that compose the physical nature of the shells (e.g., rate of weathering, alkalinity, and decomposition) will affect the depositional and post-depositional history of the deposit (Stein 1992).

Stein (1992) conducted extensive research on shell middens along the Northwest Coast of North America, that “sets the geoarchaeological standard for shell midden
study” (Goldberg and Macphail 2006:168). Stein (1992:1) describes common properties that shell middens contain including: (1) an increase porosity, permeability, and alkalinity, (2) low densities of historically diagnostic artifacts and high densities of shell, and (3) high probabilities of being saturated by the adjacent body of water. Stein argues these properties must be described and interpreted to achieve a proper interpretation as to the sites depositional history and formation (1992:1).

**Landscape Reconstruction**

The processes of reconstructing the landscape and evaluating the natural formation processes of a prehistoric site should take place after the sediments and soils have been defined and stratigraphy is established. The geomorphic landscape contains portions that either have remained stable, or are subject to constant change over time. For this reason, the components of the landscape are categorized as either being constant or dynamic elements (Waters 1992:88). The constant elements of the landscape might include features that have been forming for a long period of geologic time (e.g., mountain ranges, valleys, and basins). Dynamic components of a landscape are depositional environments that have changed during the late Quaternary Period, and are “characterized by alternating conditions of stability, deposition, and erosion” (Waters 1992:91).

Reconstructions of prehistoric landscapes are either synchronic or diachronic (Waters 1992:91). Synchronous reconstructions reveal the geomorphic processes and setting of the landscape that existed at and around the site during occupation. A reconstruction of the landscape at different points in time is a diachronic reconstruction. This reconstruction placed the people who inhabited the site in an evolving landscape
context (Waters 1992:91). Since the landscape has probably changed since its prehistoric occupation, this would make incorporating the constant and dynamic elements of the landscape an essential component to any synchronic and diachronic reconstruction.

In the following chapter, I describe the environmental background of the San Francisco Bay estuary. This overview focuses on the natural setting of the bay that includes its geomorphic setting, Quaternary paleoenvironment, and contemporary estuary environment.
Chapter 3. Environmental Background of the San Francisco Bay Estuary

Introduction

This chapter outlines the environmental history of the San Francisco Bay estuary. A description of the study areas geomorphic setting provides details of the estuary that includes dimensions, geology, soils, and present day drainage systems in relation to the research location. This is followed by a synopsis of the paleoenvironment that existed around the bay from the late Pleistocene to late Holocene. Lastly, a brief description of the current estuary environment including hydrology, climate, flora, and food web is given. This chapter is important because interpretation of the site’s reconstructed paleoenvironment is better informed when the past and present environments are understood.

Geomorphic Setting

The research area is situated within the Coast Range geomorphic province. A province is a naturally defined geologic region that displays a distinct landscape or landform (California Department of Conservation 2002). The Coast Range Province contains a series of mountains that extends approximately 1,000 km from the Transverse Ranges to the Oregon Border and roughly 130 km from the Pacific Ocean to the Great Valley in the south and the Klamath Mountains in the north (Harden 1998:252). The ranges and valleys trend northwest, subparallel to the San Andreas Fault, and the coastline is uplifted, terraced, and wave-cut. The northern and southern Coast Ranges are
separated by a depression containing the San Francisco Bay (California Department of Conservation 2002).

The San Francisco Bay is a north-trending structural trough that formed by major tectonic and folding movements. The dimensions of the bay measure approximately 80 km long, 19 to 1.6 km wide, and over half is less than 3.66 m deep (Bauman 2001). The entire San Francisco Bay is considered a part of California’s and western North America’s largest estuarine system. An estuary is defined as “a body of water, partly isolated from the open ocean, where both fresh water and marine water circulate” (Harden 1998:278). The Bay estuary consists of bedrock basins with constricting narrows, or straits, connecting them. The colder, denser, saline water from the Pacific Ocean enters the straits and circulates with the fresh water supplied by the watershed of the San Francisco Bay Delta (Malamud-Roam et al. 2006:1571).

The watershed of the Bay is almost half the size of California, and includes the entire drainage of the Sacramento and San Joaquin rivers (Harden 1998; Malamud-Roam et al. 2006). The Sacramento and San Joaquin drainage system accounts for about 40% of California’s runoff (Harden 1998:278) and supplies over 50% of the freshwater used for California’s domestic and agricultural consumption (Fox et al. 1990). The two drainage systems are responsible for 90% of the freshwater flow into the Bay estuary (Conomos et al. 1985; Nichols et al. 1986; Peterson et al. 1989; Goman and Wells 2000). This estuarine environment contains “the most extensive area of contiguous tidal marshes along the Pacific Coast of North America” (Schweikhardt et al. 2011:2301).
Much of the topography of the San Francisco Bay has been formed by tectonic activity. Tectonic movements beginning 140 million years ago in the mid-Jurassic period resulted in the Pacific Plate colliding with the North American Plate. From 140 to 28 million years ago oceanic plates, including the Kula and Farallon, collided with a subduction zone that ran the length of North America (Harden 1998:253). The plate boundary along the western edge of the North American Plate changed from subduction to transform about 28 million years ago. This occurred when the Pacific Plate encountered the North American Plate at the same time as the Farallon Plate was being consumed along the subduction zone. This change from subduction to a transform motion created the San Andreas transform boundary, also known as the San Andreas Fault (Harden 1998:253).

The Pacific Plate has shifted its course slightly over the past 28 million years as it encountered the North American Plate. One such shift 3 to 4 million years ago caused compression between the two plates and created the mountains of the Coast Ranges that are still being uplifted today (Harden 1998: 253). Three basement complexes formed from the North American and Pacific Plate encounter – Franciscan, Great Valley, and Salinian – that created the diversity of rocks and minerals found in the San Francisco Bay Area (Sloan 2006:49).

The world-famous Bay Area rocks tell a geologic story that reads like a Russian novel with a very large cast of characters. Because of our plate tectonic history, we have a crazy-quilt pattern of rocks almost defying description and order (Sloan 2006:48).
Most rocks found in the San Francisco Bay are located in the Central Belt, a part of the Franciscan Assemblage that is the remnants of several oceanic plates that collided with the North American Plate. These rocks include “isolated small blocks of exotic greenstone, blueschist, eclogite, chert, or greywacke” that “float in a matrix of highly sheared mudstone”, termed a mélange (Harden 1998:264-265).

The research areas seismicity is due in part to an active right-lateral strike-slip fault, known as the Hayward Fault. The Hayward Fault is located about 5.8 km to the north-east of the Stege Mounds (CCO-297) and appears to be the largest active fault near the study area (CA Department Conservation 2001). The most notable recorded earthquake attributed to the fault occurred in 1868 with a magnitude of 6.8 to 7.0 (USGS 1993).

Soils

Soils within and around the research area of the Stege Mounds are composed of clays and silts from the Clear Lake series and the Reyes series (UC Davis Soil Resource Lab 2014; USDA 2014). The Clear Lake series are clays that occur on 0-15% slopes from a parent material of clayey alluvium derived from metamorphic and sedimentary rocks. The series has a typical soil profile that extends 152 cm below surface and is associated with a basin-floor landform. The percent of calcium carbonates, sand particles, and pH increases with depth, while the percent of clay particles and organics decreases.

The Reyes series is silty clay formed from alluvium derived from igneous and sedimentary rock parent material. The series is associated with a salt marsh landform
with a soil development profile that extends 160 cm below surface. The percent of organic material and pH in the soil decrease in depth, while the percent of clay, sand, and carbonates remains stable. Sediments deposited in the Bay estuary are commonly called bay mud, and are typically dark-colored clay and silt that contains foraminifera and other marine microfossils that could not survive in fresh water (Harden 1998:284).

**Drainage Systems**

The research area has five major streams located near it. From north to south these are the Garrity, San Pablo, Wildcat, Baxter, and Cerrito creeks (Sowers 2006). These streams retain some flow along portions of their watercourse throughout the year. The largest drainage located near the research area is Baxter Creek, (also known as Stege Creek). Baxter Creek is an ephemeral stream with an approximate watershed 3.2 km in length, which extends from the Richmond Hills to the outlet at Stege Marsh (Sowers 2006). Banks and Orlins (1981:2.10) suggest that Baxter Creek was probably spring-fed in late prehistoric times given the small size of the watershed. This would have allowed the creek to maintain a small flow in its upper section during summer months, and may have been a seasonally flowing drainage in its lower reaches.

**Quaternary Paleoenvironment**

The landform of the San Francisco Bay Area was very different 22,000 years ago, during the late Pleistocene. During that time referred to as the last glacial maximum (LGM), worldwide sea levels were approximately 100 m lower than they are at presently due to water retained in ice sheets. The low seas levels situated the California coastline
about 25 to 50 km west of its current location (Atwater et al. 1977; Helley et al. 1979).

Masters and Aiello (2007: 50-51) describe in detail the late Pleistocene San Francisco Bay landscape as one that is characterized by broad alluvial plains incised by stream channels:

The continental shelf west of San Francisco is characterized by the Farallon platform lying beneath the Gulf of the Farallons west of the San Gregorio Fault. During the last glacial period, fluvial and aeolian sediments covered valleys that occupied the San Francisco Bay basin. These nonmarine Pleistocene deposits experienced a sustained period of subaerial exposure, weathering, and consolidation during this period of lower sea level (Helley et al. 1979). The continental shelf was more broadly exposed above sea level, with the coastline as much as 35 kilometers west of the present one. The Farallon Islands were then rugged hills rising above a broad, gently sloping plain, with a rocky coastline lying to the west. The lowland that now forms the San Francisco Bay was a broad, forested valley. Local tributary rivers and streams converged near the center of the modern Bay Area to join the river that rushed from eastern California past the present location of San Francisco and out onto the broad alluvial plain (now the continental shelf covered by the ocean). This huge river was carrying the runoff water from about 40 percent of California’s land area during a time that was cooler and wetter than the present. Once the river met the broad, flat plain west of San Francisco, it meandered to the coast, just south of the Farallon Hills. Horses, bison, camels, and mammoths roamed the Bay Valley, while smaller vertebrates lived in the brush and grass.

During the late Pleistocene and early Holocene (approximately 15000 to 9000 years ago) there was a rapid rise in sea level, totaling approximately 70 m, causing the Pacific shoreline to move eastward into the lower reaches of what is now the Bay (Meyer 2011:7). Sea levels then steadily decreased worldwide between 7000 and 6000 cal BP (Stanley and Warne 1994) allowing sedimentation from the Sacramento-San Joaquin Delta to keep pace with inundation (Atwater et al. 1979). Peat deposits in San Francisco Bay indicate that sea level reached their present position about 5000-6000 years ago (Atwater et al. 1977; Helley et al. 1979). This stabilization of sea level rise permitted the formation of salt and brackish intertidal marshes and oyster beds that began to form along the Bay’s shores.
Sediments analyzed from core samples taken on marshes that existed from 6200 to 3500 years ago show evidence that their development was initially intermittent as seen in the fluctuation between marsh deposits and subtidal estuarine deposits, also known as bay mud (Goman and Wells 2000). The fluctuation is due to variations in sea level rise and sediment loads deposited from freshwater sources. Malamund-Raom (2006:1585) notes, “sediment supplies provided by inflows from the upstream watersheds were insufficient to keep pace during the periods of more rapid sea-level rise (Goman and Wells 2000) but were sufficient to keep pace during periods of slower sea-level rise.” Marsh environments are described as developing and expanding since about 3500 cal BP (Goman and Wells 2000; Malamud-Roam 2002), and by the 1850s they covered about 2200 km square miles, nearly twice as much area as the bays (Atwater et al. 1979:347). About 95% of the tidal marshes present during the 1850s have been lost due to human development activities and land use practices (Atwater and Hedel 1976:11).

Salinity levels in the Bay’s tidal marshes over the last 3000 years have been recorded in carbon isotope, pollen, diatom records, and plant macrofossils (May 1999; Goman and Wells 2000; Byrne et al. 2001; Malamud-Roam 2002; Malamud-Roam and Ingram 2004; Starratt 2004). Goman and Wells (2000) used iron concentration and fossil seed assemblages from core samples to reconstruct both inundation and plant distributions in Bay’s estuary tidal wetlands. Malamud-Roam and Ingram (2004) used pollen and stable carbon isotope testing to reconstruct vegetation and paleosalinity in Bay tidal wetlands. Byrne (2001) and others used pollen and diatom assemblages and measurements of stable carbon isotopes to reconstruct estuarine salinity in a brackish
marsh (Watson 2006:10). Research indicates that relatively fresh water conditions existed in the Bay from 3600 to 2000 and from ca. 750-300 cal BP (Byrne et al. 2001; Malamud-Roam 2002; Starratt 2004). An increase in salinity in the estuary occurring from 1650 to 1300 cal BP, and from 1000-800 cal BP, as well as over the last 100-years, is attributed to reduced fresh water inflow. Currently, fresh water input to the Bay is lower than at any time during the Holocene (Malamud-Roam et al. 2006:1587-1594).

The changes in salinity are linked to global and regional climate fluctuations. Early Holocene climate in the Bay Area is recorded as being dry and a time of rising temperatures and sea levels. This trend continued until its peak about 5000-6000 years ago when tidal marshes were developing along protected shores of the San Francisco Bay (Atwater and Hedel. 1976:11). Climate during 4000 to 2000 cal BP was gradually cooler and wetter than the proceeding millennia. This caused a decrease in water salinity in the San Francisco Bay (Malamud-Roam et al. 2006:1589-1590). By 2000 cal BP the period of moist conditions had ended and the climate became cooler and drier (Malamud-Roam et al. 2006:1590-1591). Several mega-droughts occurred in the late Holocene, including the period known as the Medieval Climatic Anomaly (MCA) that took place from approximately 800 to 1350 cal AD (Stine 1994; Jones and Klar 2007). The MCA brought dry conditions to California and the San Francisco Bay estuary (Malamud-Roam and Ingram 2004; Jones and Klar 2007), as well as dry and drought conditions in other parts of the world (Jones and Klar 2007:301). In contrast, wet events have been documented in core samples from the Bay that date to the Little Ice Age (550-200 cal
a period that brought unusually cool and wet conditions to the San Francisco estuary and lowered salinity (Malamud-Roam et al. 2006:1570).

Severe droughts caused by the MCA probably generated problems for residents of poorly watered areas of native California (Jones and Klar 2007:302). Data analyzed from submerged and re-exposed tree stumps in Sierra Nevada lakes, bristlecone pine tree ring sequences in the White Mountains, and by declines in freshwater inflow into the San Francisco Bay indicate that California has experienced multi-decade drought conditions (LaMarche 1974; Stine 1994; Hughes and Graumlich 1995; Ingram et al. 1996; Jones et al. 1999; Byrne et al. 2001). Bartelink (2006:12) notes that while the effects the MCA had on prehistoric settlement in central California has not been systematically evaluated; there is evidence of population changes in this period. During the MCA shellmound sites in the San Francisco Bay appear to have been entirely abandoned, or came to see only sporadic use (Ingram 1998; Lightfoot and Luby 2002; Arnold and Walsh 2010). This might be related to stresses on resources and environmental degradation caused by the MCA. While sites were abandoned around the Bay, indigenous settlements appear to increase inland in places that include the lower Sacramento Valley (Wohlgemuth 2005). During this time, prehistoric populations may have “hand-crafted small-scale economies that were tailor-made to the specific environmental parameters of local places in order to weather El Niño events, droughts, and periods of global warming and cooling” (Lightfoot and Parish 2009:147).

Atmospheric conditions and precipitation events that caused fresh water to flow into the estuary appear to have attributed to fluctuations in the Bay’s salinity. Variations
in regional and local annual precipitation in California are related to changing weather patterns, including variations of El Niño/Southern Oscillation (ENSO) (Cayan and Webb 1992). The National Oceanic and Atmospheric Administration defined the causes of ENSO events:

El Niño and La Niña are extreme phases of a naturally occurring climate cycle referred to as El Niño/Southern Oscillation. Both terms refer to large-scale changes in sea-surface temperature across the eastern tropical Pacific. Usually, sea-surface readings off South America's west coast range from the 60s to 70s F, while they exceed 80 degrees F in the "warm pool" located in the central and western Pacific. This warm pool expands to cover the tropics during El Niño, but during La Niña, the easterly trade winds strengthen and cold upwelling along the equator and the West coast of South America intensifies. Sea-surface temperatures along the equator can fall as much as 7 degrees F below normal.

El Niño and La Niña result from interaction between the surface of the ocean and the atmosphere in the tropical Pacific. Changes in the ocean impact the atmosphere and climate patterns around the globe. In turn, changes in the atmosphere impact the ocean temperatures and currents. The system oscillates between warm (El Niño) to neutral (or cold La Niña) conditions with an on average every 3-4 years (US Department of Commerce 1998).

This event causes an increase in sea surface temperature along the California coast, a reduction in the upwelling of cold, nutrient-rich waters, and occasionally the creating of high precipitation events and heavy seas. Wet periods that caused major flooding events in the Bay Area correlate to high precipitation events related to large scale-atmospheric changes, such as the strength and frequency of ENSO (Malamud-Roam et al. 2006; Masters and Aiello 2007; West et al. 2007; Goman et al. 2008).

Environment of the San Francisco Bay Estuary

The San Francisco estuary contains the most extensive area of contiguous tidal marshlands along the Pacific Coast of North America and has a watershed that covers about 96,560 km², or roughly 40% of California (Cohen 2000:2; Schweikhardt et al.
The Delta is located in the northern most section of the estuary, and is an approximate 1609 km² triangle of diked and drained wetland where fresh waters from the San Joaquin and Sacramento drainages empty into the San Francisco Bay. The Bay, measuring approximately 1165.5 km², is located downstream of the Delta and is comprised of four smaller bays that include Suisun Bay, San Pablo Bay, Central Bay, and South Bay (Cohen 2000).

About 95% of the Bay’s historic tidal marshes have been diked or filled since the mid-1850s (Atwater and Hedel 1976:11; Cohen 2000:26; Josselyn 1983:14). Between 1860 and 1930, a majority of the Delta’s 1367 km² of marshland had been diked off and converted to farmland, while downstream 80% of the Bay’s marshes and intertidal mudflats were turned into salt ponds, cow pastures, or marketable real estate. These development activities “reduced the area open to the tides from over 800 to about 144 km² in the Delta, and from 1287 to 804 km² in the Bay” (Cohen 2000:3-4).

Hydrology

The estuary is composed of two sections that link it to the ocean and include the northern and southern reach. The northern reach extends from the Delta through Suisun, San Pablo and Central bays, where the water circulation is heavily influenced by fresh water input from the Sacramento and San Joaquin rivers. This fresh water inflow causes a decrease in surface water salinity from the Golden Gate to the Sacramento and San Joaquin Delta (Atwater and Hedel 1976:16). The southern reach, located in the South Bay, receives less than one tenth as much fresh water from its tributaries than the
northern reach, and is often dominated by the combination of ocean water and northern reach water (Cohen 2000:5).

The difference in salinity can cause water stratification in the estuary, as salt water is heavier than fresh water. This usually occurs at deeper depths as currents and wind usually keep the water near the surface mixed throughout the year. This stratification causes estuarine circulation in the northern reach (Cohen 2000:6). Estuarine circulation occurs when downstream freshwater flow near the surface layer creates a smaller upstream current of heavier saltwater near the bottom of the channel. This circulation is usually well developed near the Carquinez Strait (Cohen 2000:6). The point where both currents meet and cancel out, called the null zone, is usually found at the bottom of the upper end of the Strait. An entrapment zone, a region where suspended particles and small organisms accumulate, may form at or downstream of the null zone.

Tides in the estuary are semi-diurnal, with two unequal high tides, and two unequal low tides, in a roughly 25-hour period (University of Nevada, Reno 2014). Twice each day a tidal prism of approximately 1603.6 gigaliters of salt water from the Pacific Ocean – about one quarter of the estuary’s total volume – moves in and out of the estuary and is split about evenly with the northern and southern reaches (Cohen 2000:5). The amount of freshwater entering the Bay is much less, measuring approximately 61.68 gigaliters.

Climate

The climate of the research area is a Type CsB using the Koppean Classification, or Cool Summer Mediterranean (Kesseli 1942: 477-78). The annual mean temperature is
14 degrees C with an average rainfall of 60.04 cm that precipitates predominately in the winter months (US Climate Data 2015). Fog in the San Francisco Bay is more prevalent from April to July when persistent winds from the north create strong southward currents, causing upwelling of cold bottom water along the coast that lowers the surface temperature (Cohen 2000:7). This chilled water is then passed over by moist ocean air creating fog that is often held in place by the mountains of the coast range. Fog tends to dissipate from August through November as winds diminish, weaker currents run northward, upwelling stops, and the surface waters grow warmer and diminish the fog (Cohen 2000:7).

**Flora**

The Bay Area contains an abundance of ecological habitats that range to saltwater and fresh water marshes, mudflats, sandy beaches, open waters, grasslands, and woodlands (Schoenherr 1992: 672-687). Marshes fringe the estuary and represent the transition to terrestrial ecosystems (Goman 2005), and contain different vegetation species that are clearly zonal (Atwater and Hedel 1976; Josselyn 1983). The zones are distinguished by different vegetation communities that vary in environmental factors such as length and frequency of inundation, salinity, soils, and elevation, and are depicted in Figure 2 (Cohen 2000:8).

Andrew Cohen (2000:9) described tidal and freshwater marsh vegetation zonation in detail:

Where exotic plants have not invaded, strands of Pacific cordgrass, which can tolerate relatively long periods of flooding, fringe the water’s edge and line the lower channels. Typically, the largest section of marsh is a flat, salty, waterlogged plain above the cordgrass, covered with the succulent, branching stems of pickleweed. Here and there, where water circulation is limited, tangled nets of orange, thread-like dodder, a parasitic
vine, overgrow the pickleweed. Near the marsh’s landward edge the pickleweed mixes with other low-growing plants such as saltgrass, fat hen, alkali heath, arrowgrass, jaumea and marsh lavender, along with taller shrubs of gumplant. These plants grow on the slightly-elevated and better drained soils alongside channels, so that otherwise hidden channels are often marked by lines of yellow-flowered gumplant winding across the pickleweed plain.

In more brackish marshes the zones are less distinct, but show up best on steep banks. The tall, round, grayish-green stems of California tule crowd the lowest level. Triangular-stemmed alkali bulrush dominates the middle zone in the saltier regions, with Olney’s bulrush and cattails more common at this level in fresher water upstreams. In the highest zone, pickleweed and saltgrass grow on the saltier soils, with Baltic rush and brass buttons (a non-native member of the aster family) on the fresher soils. A few rare plants are found in these marshes, including softs bird beak, Mason’s lilaeopsis and Suisun thistle. While most of the Estuary’s brackish tidal marsh lies within Suisun Bay, smaller brackish marshes line the Petaluma and Napa rivers north of San Pablo Bay, and some South Bay sloughs where treated wastewater discharges have freshened former salt marshes.

Hinde (1954) described an investigation on plant distributions in relation to tidal inundation in the San Francisco Bay in 1954. He found the range of *Spartina foliosa* (cordgrass) to be from 1.6 to 2.5 m above mean lower low water (MLLW). The range of *Salicornia virginica* – now with the taxonomic name *Sarcocornia pacifica* and
commonly referred to as pickleweed (Calflora 2014) – to be from 1.9 to 3.1 m above MLLW, and that for *Distichlis spicata* (saltgrass) to be from 2.8 to 3.1 m above MLLW. Vegetation found in each of these zones is inundated below tides for different lengths of time. *Spartina foliosa*, and other species growing at the lower edges of the marsh zone, are submerged for about nine hours at a time. *Distichlis spicata* and species inhabiting the upper zones are inundated for less than five hours at a time (Anderson 2006:26).

Goman and others (2008) investigation of a salt marsh located at China Camp State Park, where mean winter and summer salinities average 20-30%, revealed the low salt marsh zone was dominated by *Spartina foliosa*. Previous investigations at the marsh noted mixed strands of *Spartina foliosa* and *Scirpus* (bulrush) within the same zone (Goman 2001). The ecotone between low marsh and high marsh was abrupt with *Salicornia virginica* dominating the high marsh plain. Species located on the higher marsh plain included *Distichlis spicata*, *Jaumea carnosa*, and *Grindelia stricta*.

Anderson (2006:26-27) described the typical vegetation found in brackish and freshwater marshes that are situated along river courses, creeks, and in brackish areas landward of salty marsh environments. Common plant species include various tules (*Schoenoplectus americanus, S. validus, S. acutus, S. californicus*, formerly in the genus *Scirpus*), three species of cattails (*Typha latifolia, T. angustifolia, and T. domingensis*), sedges (many species of *Carex*), common reed (*Phragmites australis*), water plantain (*Alisma plantago-aquatica*), arrowhead (*Sagittaria* spp.), and yerba mansa (*Anemopsis californica*).
Atwater and Hedel (1976:20) argued that elevation and water salinity are the principal ecological factors that control distribution of seed plants in the natural tidal marshes of the northern San Francisco Bay. Their study showed that the salinity of water that inundates the marshes determines the regional distribution of plant species and communities. A small number of salt-tolerant species typically occupied marshes flooded by nearly undiluted seawater, whereas a more diverse plant community inhabited marshes containing fresh to brackish waters (Atwater and Hedel 1976:20).

Their study observed that vegetation varied between the upper, middle, and low marsh zones. The most diverse group of tidal plants inhabited the high-marsh surfaces and included Salicornia virginica, Distichlis spicata, Atriplex patula, Jamea carnosa, Grindella cuneifolia, and Limonium commune. Plants observed in the middle marsh zone contained species that generally grew between high and low marsh surfaces. These included Spartina foliosa, Salicornia virginica, Scirpus robustus, Salicornia rubra, and others. The low-marsh zone contained Spartina foliosa, Scirpus californicus, and possibly Scirpus acutus (Atwater and Hedel 1976:25-31).

Josselyn (1983) studied the zonation of plant composition in tidal marshes of the San Francisco Bay. The study showed salt marshes to occur throughout the south, central, and San Pablo Bays, while brackish marshes dominated Suisun Bay and in areas of local freshwater discharge (e.g., Petaluma and Napa rivers, and several south bay rivers) (1983:34). The report showed that the marshes were dominated by vascular plants and can be used to delimit marsh boundaries. Most plants species recorded in salt marshes included Spartina foliosa and Salicornia virginica. Species of plants associated
with *S. virginica* included *Distichlis spicata* and *Atriplex patula* found in the upper zone of the marsh. The dominant genera of plants recorded in brackish marshes were *Scirpus* and *Typha* (Josselyn 1983:34-43).

Investigations on a fresh and brackish marsh in the Bay Area revealed that both marsh environments support a mixture of *Scirpus acutus*, *Scirpus californicus*, and *Typha angustifolia* below MHHW (Goman 1996). Above MHHW *Scirpus robustus* dominated the region of a brackish marsh near the Carquinez Strait. This area was situated near the mixing zone of fresh and salt water containing surface salinity ranging from zero to 18%. *S. americanus* dominated the MHHW region at a freshwater marsh near the Delta, where water flowing from the San Joaquin and Sacramento had a salinity ranging from zero to 5%. Both brackish and freshwater marsh types supported patches of *Distichlis spicata* and *Salicornia virginica* above MHHW (Goman 1996).

**Food Web**

The Bay estuary contains a variety of phytoplankton, zooplankton, shrimp, fish, and marine mammals that drift or swim in the different saline regions and contribute to the food web (Cohen 2000:8). The estuary’s marshlands and mudflats provide the primary source of shellfish, such as clams, oysters, mussels, and abalone. Phytoplankton consist of small microscopic plants that form the base of the Bay’s food chain, and in the right environment conditions (e.g., tides, river flow, temperature, and rate of being eaten) their population surges, known as blooms. These blooms consist primarily of single-celled algae with silica shells called diatoms. Blooms occur less often in the southern reach compared to the northern due to the phytoplankton’s limited growth caused by
filter-feeding benthic invertebrates, which are 10 times more abundant in the South Bay (Cohen 2000:15). Diatom blooms help support a large population of zooplankton including copepods, water fleas, and tiny opossum shrimp. Species that feed on zooplankton include grass shrimp, delta smelt, crabs, and mollusks, and are in turn eaten by larger predators (Cohen 2000:14).

Most of the Bay estuary in underlain by mud that creates a soft-bottom benthic habitat for clams, worms, shrimp, and other species. The invertebrate fauna in the Bay’s tidal marshes can be divided into three major groups: benthic infauna, epifauna, and terrestetail anthropods (Josselyn 1983:49). Typical mudflat infaunal organisms include the Baltic clam (*Macoma balthica*) and the Bent-nosed clam (*Macoma nasuta*). Epifauna include the yellow shore crab (*Hemigrapsus oregonensis*), shore crab (*Pachygrapsus crassipes*), and hornsnail (*Cerithidea californica*). The most abundant animals within the tidal marsh are terrestrial anthropods that consist of a vast array of insects and spiders (Josselyn 1983:54).

A variety of fish species inhabit the Bay estuary and tidal wetlands. Cohen (2000:13) describes that out of roughly 120 regularly occurring estuary fish species, two are estuarine fish (delta smelt and longfin smelt), about one quarter are freshwater fish, two thirds are marine-derived fish that range various distances into the estuary, and the remainder are anadromous (e.g., salmon and steelhead trout). The tides, currents, and changes in inflows will drastically alter the provenance and quantity of where fish are located (Cohen 2000:13).
Other fish communities that populate the wetlands include Leopard Shark (Triakis semifasciata), Bat Ray (Myliobatis californica), Topsmelt (Atherinops affinis), Arrow goby (Clevelandis ios), Yellowfin goby (Acanthogobius flavimanus), Staqhorn sculpin (Leptocottus armatus), Splittail (Pogonichthys macrolepidotus), Tule perch (Hysterocarpus traski), Northern anchovy (Engraulis mordax), and a variety of others (Josselyn 1983:59-61).

A vast number of avian species use the San Francisco Bay marshes as a stopover point on their route along the Pacific Flyway, especially during the migratory seasons (Josselyn 1983: 62). The migrating shorebirds number in the hundreds of thousands and come to the Bay from nesting grounds in the Canadian prairies and as far away as Siberia (Cohen 2000:21). Mudflat and saltpond habitats provide the highest bird density populations while vegetated marsh areas provide the lowest. Bird species recorded in the marshes include avocet (Recurvirostra sp.), willet (Tringa semipalmata), dowitcher (Limnodromus sp.), curlew (Numenius sp.), western sandpiper (Calidris mauri), least sandpiper (Calidris minutilla), godwit (Limos sp.), California clapper rail (Rallus longirostris), and yellowthroat (Geothlypistrichas sinuosa) (Josselyn 1983:62-65; Cohen 2000:21). Species of ducks, geese, pelicans, gulls, shore birds, and other migratory fowl are also observed in the Bay tidal marshes (Josselyn 1983:64).

Marine mammals known to inhabit the San Francisco Bay estuary include sea otter (Eninydra lutris), harbor seal (Phoca vitulina), and the California Sea Lion (Zalophus californianus). The harbor seal is the largest mammal that uses the salt marshes. These mammals are “typically hauled out on pickleweed and saltgrass at high
tide and on the mudflat at low tide (Josselyn 1983:72). The sea otter, whose population once numbered in the thousands, was thought to be absent from the Bay after the last few were shot in 1846. However, they are now occasionally viewed in the Bay and are believed to be slowly repopulating its waters (Cohen 2000:39).

In the following chapter, I discuss the cultural background information of the study area that includes defining taxonomic systems used to describe cultural sequences of the prehistoric Bay Area. This is followed by an ethnographic overview of the pre-contact Ohlone that lived in Richmond and surrounding areas, as well as cultural periods that occurred in the City of Richmond from 1775 to post World War II.
Chapter 4. Cultural Background

Introduction

This chapter provides an overview of the cultural history of the prehistoric peoples who inhabited the areas along the San Francisco Bay estuary, and more specifically, the greater Contra Costa area. I begin the chapter by describing three taxonomic systems that describe the cultural sequences of Central California and the San Francisco Bay Area, giving specific attention to a hybrid system that incorporates two previously developed systems of classification (Milliken et al. 2007). This is followed by a discussion on ethnography of the region that will set the framework for interpreting the cultural occupancy of shellmounds found along the Bay estuary landscape. Lastly, a discussion on the localized history of the study area will focus on how people may have interacted and affected the landscape.

Prehistoric Overview

The prehistory of the San Francisco Bay Area spans thousands of years and contains hunter-gatherer populations who left behind a rich and diverse archaeological record. This has created cultural sequence systems that contain a large number of diverse cultural aspects that some professionals in the field describe as a complex “nightmare of detail” (Milliken et al. 2007:105). This vast amount of detail is warranted due to the amount of archaeological and linguistic variations that define the Bay’s cultural region.

Three taxonomic systems have been developed that describe the cultural chronology of the San Francisco Bay Area and can be arranged in these primary
categories: (1) the Central California Taxonomic System, (2) the Archaic-Emergent Culture History Scheme, and, (3) a hybrid System that combines aspects of several schemes (Milliken et al. 2007). These three systems organize the archaeological record into coherent units of observation and comparison and are described by Milliken and others below (2007:101):

- The Early-Middle-Late Period nomenclature of Beardsley (1954), dubbed the Central California Taxonomic System (CCTS) by Gerow (1968) is used by South Bay archaeologists (Bellifemine 1997; Cartier et al. 1993; Hylkema 2002) and some Central Bay archaeologists (Broughton 1999; Lightfoot and Luby 2002).

- The *Archaic-Emergent* temporal structure of Fredrickson (1973, 1994), with specific cultural configurations identified by economic patterns, stylistic aspects, and temporally constricted regional phases, is used by North Bay archaeologists (Stewart 2003; White et al. 2002) and some Central Bay archaeologists (Meyer and Rosenthal 1997).

- A hybrid system, marking large blocks of time with the Early-Middle-Late Period structure and differentiating units of culture with Frerickson’s pattern, aspects, and phase concepts, is used by some Central Bay archaeologists (cf. Banks and Orlins 1985:28-51; Wiberg 1996:123-128, 1997:9-17).

The hybrid system is established by the dated sequence of *Olivella* shell bead horizons and assigns a temporal framework to archaeological assemblages. A total of four dating schemes have been implemented (A, B, C, and D). Scheme A, developed by Robert F. Heizer in 1958, was based on 17 radiocarbon dates and associated cultural material. It placed the beginning of the Late Horizon (Late Period) at 300-500 AD (uncalibrated radiocarbon years) (Milliken et al. 2007:105). A revised shell bead sequence, Scheme B, was created by Bennyhoff and Hughes in 1987 and was based on 180 Central California radiocarbon dates that “were neither calibrated nor corrected for the marine reservoir effect” (Milliken et al. 2007:105). This sequence identified 11 bead horizons and moved the Middle/Late Period Transition (MLT) forward from 700 to 900
AD. Scheme C combined the findings from Scheme A (Heizer 1958) and B (Bennyhoff and Hughes 1987:147). Lastly, Groza (2002) developed a revised sequence based on 103 accelerated mass spectrometer (AMS) calibrated radiocarbon dates on 10 of Bennyhoff’s 11 *Olivella* bead horizons, shifting the bead horizon dates forward in time as much as 200 years (Millken et al. 2007:105).

This section briefly describes the series of cultural changes that have occurred in the San Francisco Bay area over the last 10,000 years by using the hybrid system that incorporates the Early-Middle-Late Period temporal sequence and pattern-aspect-phase cultural sequence. The chronological periods include:

- **Early Holocene (Lower Archaic)** (8000 to 3500 cal BC)
- **Early Period (Middle Archaic)** (3500 to 500 cal BC)
- **Lower Middle Period (Initial Upper Archaic)** (500 cal BC to cal AD 430)
- **Upper Middle Period (Late Upper Archaic)** (430 to 1050 cal AD)
- **Initial Late Period (Lower Emergent)** (1050 to 1550 cal AD)
- **Terminal Late Period** (>1550 cal AD)

**Early Holocene (Lower Archaic) 8000 to 3500 cal BC**

Very little is known about human populations that inhabited the immediate Bay Area during this time, while there have been significant finds around the edges of the region (Milliken et al. 2007; Arnold and Walsh 2010). One of the most notable is the BART skeleton (Bickel 1978). The male skeleton was encountered 14 m below ground surface and 7.9 m below sea level during the construction of the Bart Area Rapid Transit tube in 1969 (Gerow 1981:4). The skeleton is the oldest encountered in the region with
its bones dating to roughly 5,000 years in age by radiocarbon testing (Arnold and Walsh 2010:67). Several investigations around the Bay Area suggest a generalized mobile forager pattern emerges around the edges of the Bay at this time. Archaeological finds including millingslabs, and diverse varieties of large wide-stemmed and leaf-shaped projectile points, are attributed to the foraging pattern (Milliken et al. 2007:114).

**Early Period (Middle Archaic) 3500 to 500 cal BC**

Sedentism, regional symbolic integration, and increased regional trade characterize the beginning of the Early Period for the Bay Area. This is indicated by new groundstone technology and the first cut shell beads observed in mortuary contexts. Mortar and pestle technology that appeared about 3400 BC is believed to be associated with acorn harvesting and processing (Milliken et al. 2009:71). The pattern in which millingstones are absent or replaced by handstones is known as the Stege Phase of Fredrickson’s (1973) Berkeley Pattern (Milliken et al. 2009:71). Shell beads that are rectangular cut are makers of the Early Period in California and Nevada (Milliken et al 2009:71).

A single cut bead, the *Olivella* grooved rectangle, was recorded at the San Bruno Mound (Clark 1998). This bead represents the earliest cut bead horizon (3400 to 2500 cal BC) in the San Francisco Bay Area. The earliest known *Olivella* rectangle beads with drilled perforations was encountered in a burial provenience containing red ocher at CCO-637, a prehistoric site located at Los Vaqueros Reservoir in Contra Costa County that contained shell dating to 4,800 years ago (Rosenthal and Meyer 2000). Rectangular *Haliotis* beads found at the Sunnyvale Red Burial site, SCL-832 (Cartier 2002), as well as
the *Olivella* bead found at CCO-637, are markers of Early Period bead horizon and continued in use until 2,800 years ago (Milliken et al. 2007:115). The West Berkeley mound (ALA-307), containing rich anthropogenic soil, is suggestive of a sedentary lifeway during this period (Wallace and Lathrop 1975). Similarly, a large oval house floor of a permanently inhabited village in Walnut Creek (CCO-309) has been dated to 1500 BC (Price et al. 2006).

A shift in settlement patterns from forager to semisedentary land use was recorded at shellmounds in West Berkeley (ALA-307), Ellis Landing (CCO-295), and Pacheco (MRN-152). This was indicated by the presence of mortars and pestles and ornamental grave associations (Milliken et al. 2007:115). Mortar and pestle use in the Bay Area is documented shortly after 4000 cal BC, and includes pestles found at CCO-637 that date to 3800 cal BC (Rosenthal and Meyer 2000). Another site suggesting a change in settlement pattern is the Rossmoor site (CCO-309), excavated in 2005. This site contained an elliptical house floor with postholes, indicating sedentism or semisedentism in the interior East Bay (Price et al. 2006). Cultural material recorded around the Bay during the Early Period is interpreted to represent lowland sedentary collectors living with upland mobile foragers who occasionally visited the lowland marshes (Milliken et al. 2007:115).

**Lower Middle Period (Initial Upper Archaic) 500 cal BC to 430 cal AD**

Shifts in shell bead styles occur during the Lower Middle Period and Early Middle Transition Period (EMT). The once dominant rectangular cut shell beads that had been in use for 3,000 years, disappear in the Bay Area, Central Valley, and southern
California (Milliken et al. 2007:115). Split-beveled and tiny saucer *Olivella* beads appear during the Early Middle Transition period (EMT), but spire-looped *Olivella* beads were more common than the cut beads (Luby 2004).

A cultural climax in the San Francisco Bay is recorded during the Upper Archaic period (200 cal BC to 430 cal AD) and is marked by the new appearance of cultural material such as shell ornaments and bone tools. New material includes barbless fish spears, elk femur spatulae, tubes, and whistles (Elsasser 1978:39). New circular *Haliotis* ornaments appear at this time, while *Olivella* saucer beads became common (Milliken et al. 2007:115). Central and North Bay sites indicate the appearance of coiled basketry being produced by awls made from split cannon bones (Bennyhoff 1986:70; Bieling 1998:218).

**Upper Middle Period (Late Upper Archaic) 430 to 1050 cal AD**

The Upper Middle Period in Central California is characterized by a major cultural disruption and the introduction of three bead horizons (M2, M3, and M4) from the Meganos complex. The previous *Olivella* saucer bead trade network, associated with the M1 horizon, disappears. Milliken and others (2007:116) note, “53 of 103 known M1 sites were abandoned, sea otter bones spiked in the remaining sites, and the Meganos extended mortuary pattern began to spread in the interior East Bay (Bennyhoff 1994a, 1994b)”.

The Meganos complex first appears at the Santa Rita Village site (ALA-413) in the Livermore Valley. Archaeological material recorded included roughly 30,000 *Olivella* saucer beads from the M1 Bead Horizon, noted to be the largest documented bead lot in California (Milliken et al. 2007:116). The M1 Bead Horizon was replaced
with the M2a and then the M2b. The M2a bead style is described as rough-edged full saddle with high perforations, while the M2b is noted as a saddle bead with tiny 1.0- to 1.5-mm perforations (Milliken et al. 2007:116). Cultural items that appear in the M2a and M2b horizons include show blades, fishtail charmstones, new *Haliotis* ornament forms, and mica ornaments.

Bead Horizon M3 (600 to 800 cal AD) is described as being the climax of “stylistic refinement”, and is marked by “small, delicate square saddle *Olivella* beads in burials, occasionally with small, poorly shaped *Olivella* saucer beads, often in off village component cemeteries” (Milliken et al. 2007:116). The Meganos mortuary complex spreads from the interior to the edges of the Bay at the BART site (ALA-293) in Fremont, and into the Santa Clara Valley (SCL-302) (Milliken et al. 2007:116). The last bead horizon in the Late Upper Archaic Period, M4, dates to 800 to 1050 cal AD. A cultural postclimax in this period is represented in material assemblages that includes the devolution of the *Olivella* saddle bead template, the appearance of various *Haliotis* ornament styles, and an overall lack of grave accompaniments (Milliken et al. 2007:116).

**Initial Late Period (Lower Emergent) 1050 to 1550 cal AD**

The Late Period shell bead horizon is characterized by an increase in social complexity in the San Francisco Bay Area. Most bone tools and ornament types from the previous Middle Period disappear by this time. Mortuary practices shift from interring the deceased with simple and numerous ornaments, to interring them with “finely wrought wealth objects” that infers large amounts of time was invested (Milliken et al. 2007:1160). The Middle/Late transition period (MLT), beginning around 1000 cal AD,
is marked by new *Olivella* bead types and *Haliotis* ornaments appearing in areas of Contra Costa (CCO-308), Alameda (ALA-42), and Santa Clara (SCL-690) (Milliken et al. 2007:116). These objects are the initial markers of the Augustine Pattern, and are included in Bead Horizon L1 assemblages. Other cultural items attributed to this pattern include the arrow, flanged pipe, *Olivella* callus cup, and the banjo effigy ornament (Bennyhoff 1994b).

The Augustine Pattern, also known as the Emergent Period (Fredrickson 1973), saw a decline in new sites near the bay shore, but an increase of sites inland (Arnold and Walsh 2010:73). New lithic assemblages, including the first arrow-sized projectile point types, enter the Bay Area after 1250 cal AD, and consists of the Stockton serrated series (Milliken et al. 2007:117). The Stockton Cluster is regarded as a significant development in California lithic technology as “the care given to these forms in manufacture reflects tremendous skill and mastery of controlled pressure flaking that is unparalleled in California and most of North America” (Justice 2002:352). The appearance of the bow and arrow coincides with a drop in lithic production of bifaces and debitage at the Napa Glass Mountain quarries, while manufacturing of debris from that source increased in the interior East Bay (Milliken et al. 2007:117).

Increased social stratification is recorded with a change in mortuary practices, including partial cremation, “associated with the wealthiest of offering” (Milliken et al. 2007:117). The amount of shell beads that are found within burial contexts decreases in this period, but the amount of uncommon wealth items associated with high status burials and cremations increases (Fredrickson 1994:62; 1974:66). The Augustine Pattern was “a
complex collector pattern” and was argued by Fredrickson (1973) as a period associated with an emergent culture, “his definition equivalent to initial agricultural village life elsewhere, rather than a typical hunter-gatherer Archaic culture” (Milliken et al. 2009:73).

**Terminal Late Period (>1550 cal AD)**

During the Terminal Late Period, the L1 *Olivella* Bead Sequence and cup beads abruptly disappear, while the L2 Bead Horizon markers, which consist of clamshell disk beads, spreads across the North Bay (Milliken et al 2007:117). In the same region, new tools and beads appear including the toggle harpoon, hopper mortar, plain corner-notched arrow projectile point, clamshell disk beads, and magnesite tube beads (Milliken 2007:117). The only beads found in the south and central Bay mortuaries consist of *Olivella* looped and spire-looped, but occur in far smaller amounts than the previous L1 Bead Horizon (Milliken and Bennyhoff 1993:392).

There is still professional debate concerning the meaning of change of artifact types and mortuary wealth distribution after 1500 cal AD, but the shift indicates “another upward cycle of regional integration was commencing when it was interrupted by the Spanish settlement in the Bay Area in 1776” (Milliken et al. 2007:118).

**Ethnographic Overview**

The following section provides a brief ethnographic background of the various Ohlone peoples who inhabited the Bay Area, including the Chochenyo Ohlone who lived in the thesis study area. Much of this section addresses the Ohlone before Spanish
contact and summarizes their language and territory, political and social organization, trade and exchange, and subsistence.

Language and Territory

Seven languages were spoken in the San Francisco Bay Area at the time of Spanish settlement in 1776. The linguistic area extended from Bodega Bay in the North, Monterey Bay in the south, and eastward to the Sacramento River. These languages included Southern Pomo, Wappo, Patwin, Coast Miwok, Bay Miwok, Karkin Coastanon, and San Francisco Bay Costanoan (Milliken et al. 2009:99). The Spanish referred to all native people living on the coast as “costeños”, meaning “people of the coast.” This term was later anglicized to “Coastanoan” as a linguistic identifier to native people living in the San Francisco and Monterey Bay regions who were thought to have spoken common languages (Yamane 2002:1). Variations of the term have been found in mission records, and may have been derived from the village of “Oljon” on the San Mateo coast (Yamane 2002:1). Milliken et al. note that the term “Ohlone” was first applied to the Coastanoan language family as a whole in Malcolm Margolin’s (1978) popular book *The Ohlone Way*, and has since become a term used to identify the people (2009:45-46).

The Ohlone languages are a part of the Proto-Utian language family associated with complex hunter-gatherer societies. These Proto-Utian groups, speakers both of Ohlone and Miwok languages, are thought to have entered the Delta region about 4,500 years ago, displacing Hokan speakers within this region (Moratto 1984:293). Eight known surviving Ohlone languages have been related to tribal groups. They include: Karkin (Carquinez Strait), Chochenyo (East Bay), Ramaytush (San Francisco Peninsula),
Tamien (Santa Clara Valley), Awáswas (Santa Cruz area), Mutsun (southern Santa Clara County and San Benito County), Rumsien (lower Carmel Valley and the Monterey area), and Chalon (northern Monterey County east of Mission Soledad) (Yamane 2002:1). About 2,000 people who occupied the east shore of San Francisco Bay between Richmond and Mission San Jose, and the Livermore Valley, spoke the Chochenyo dialect at the time of Spanish contact (Levy 1978:485).

Political and Social Organization

The pre-contact Ohlone belonged to local independent political groups led by the elders of extended families. In many areas, the number of families banded together in miniature tribes under the leadership of a single multi-family headman (Milliken 2002:25). These miniature tribes were termed tribelets by Kroeber (1955:307), “I deliberately coined the name tribelet to designate a sovereign though miniature political unit, which was land-owning and maintained its frontiers against unauthorized trespass.” The individual tribelet had one, two, or three semi-permanent villages of 50 to 150 persons, and a number of temporary camps within that groups territory (Levy 1978). The reconstruction of tribal locations – based on primary documents including mission records, diaries, and maps – indicates the Huchiun (Cuchillion, Juchum, Juchium, and Juchillion) as controlling the bay shore area that is now the Richmond Inner Harbor during the late 18th century (Milliken 1981:4.2; 1995:225, 228-229).

The tribelets main headsman, or chief, was mainly held by males and followed along patrilineal lines, passing from father to son (Levy 1978:487). The role of the chief included acting as a leader of a council of elders (Harrington 1933:3), serving as advisor
to the community, responsibility for feeding visitors, providing for the impoverished, directing ceremonial activities, caring for captive grizzly bears and coyotes, and directing hunting, fishing, and warfare expeditions (Levy 1978:487).

Family and community was the basis of social life for the Ohlone living along the eastern shores of San Francisco Bay (Margolin 1978). The villages included family dwellings constructed from thatched tule, grass, wild alfalfa, fern, or Carrizo grass (Levy 1978:492). The dwellings were supported by a framework of poles with pole binders tied with willow witches, and were inhabited by an average of 15-members of a nuclear or extended family (Levy 1978:488).

Trade and Exchange

Archaeological evidence indicates that the Ohlone participated in an exchange network that ranged outside of their tribal territory that allowed the exchange of natural and cultural commodities to be traded or bartered for. The Plains Miwok, Sierra Miwok, and Yokuts are noted as important trading partners with the Ohlone (Levy 1978:488). The Yokuts provided the Ohlone with pine nuts (Davis 1961:23), and the Ohlone provided them with mussels, abalone shells, salt, and dried abalone (Levy 1978:488). Obsidian from the north end of the Napa Valley is the dominant material found at archaeological sites within Chochenyo territory throughout the archaeological record (DeGeorgey 2013:16).

Subsistence

The Ohlone made their primary living by harvesting the plant and animal resources from their local environments (Milken et al. 2009:61), with acorn dependency
the first and foremost (Arnold and Walsh 2010:64). Hunting and gathering of foods consisted of, but was not limited to: various grass seeds, berries, geophytes, and young shoots, black-tailed/mule deer, tule elk, pronghorn antelope, grizzly bears, mountain lions, sea lions, water fowl, and other marine and terrestrial species. Milliken (2002:25) summarizes the lifestyles of the Ohlone who inhabited the Santa Cruz-Monterey Bay region prior to European contact, noting that sexual division of labor was practiced:

Villages and campsites swelled, shrank, or abandoned at various seasons of the year, as families moved about to harvest locally abundant wild plants and animals. Men hunted rabbits, deer, elk in the fields, ducks, and fish in the lagoons. Women gathered greens, seeds, and acorns in the seasons. People wore very little in the benign climate; women wore tule skirts; men and children wore nothing at all. Special feather costumes and shell ornaments were brought fourth at festival times, when multiple village groups would meet to share foods, trade, and perform traditional ceremonies.

Tribal settlement on various geographically and ecologically different landscapes likely influenced the material used in subsistence technologies (e.g., redwood planks versus tule bundles for house construction), as variations of these techniques has been well documented between costal, Russian River, and Clear Lake Pomo people north of the Bay Area (Milliken et al. 2009:61).

Historic Overview

This section briefly summarizes the historic developments that occurred around and within the study area located in what is now Richmond, California. The historical context is divided into five periods: the Spanish Period (1775 – 1822), Mexican Period (1822 – 1848), American Period (1848 – 1894), Incorporation Period (1894 – 1939), and Wartime Period (1939 – 1945).
Spanish Period (circa 1775 – 1822)

The San Carlos, a 58-foot long two-mastered brig, was the first ship to enter into the San Francisco Bay (Milliken et al. 2009:92). It arrived on August 6th, 1775 with a thirty-man crew under the direction of Lieutenant Juan Manuel de Ayala (Galvin 1971; Milliken 1995:40-41). They explored Angel Island from August 13th until September 7th 1775, taking extensive notes about the cultural interactions between the Spanish and members of the local tribes (Galvin 1971). During their 48-day visit, the Spanish frequently gave the local people strings of glass beads, earrings, and other items (Milliken et al 2009:93). The ship made several anchorages off the Marin Peninsula and Angel Island, and the ship’s boats charted San Francisco Bay and San Pablo bays. The notes taken by the Captain and Chaplin contain a great amount of information about interactions with the Huimens of southern Marin Peninsula and Huchiuns of the Point Richmond vicinity in the East Bay (Galvin 1971). Father Santamaria describes the meeting of Huchiun men during their visit to San Carlos in August 1775:

The Indians who came on this occasion were nine in number, three blind old men, two of them were sight impaired by cataracts of some sort. The six others were young men of good presence and fine stature. Their coloring was not as weak as we have seen in the Indians of Carmel. They were no means filthy, and the best favored were models of perfection... Besides comely elegance of figure and quite unique faultless countenance there was also—as their chief adornment—the way they did up their long hair: after smoothing it well they stuck in it a four–toothed wooden comb and bound up the end in a net of cord and very small feathers that were dyed a deep red; and in the middle of coiffure was tied a sort of ribbon, sometimes black, sometimes blue. Those Indians who did not arrange their in this fashion did it up in a club so as to keep it in a closely woven small net that seemed to be a hen-like fibers dyed a dark blue (Santamaira quoted in Galvin 1971:29-31).

Mission Dolores (also known as Mission San Francisco de Asis) and the San Francisco Presidio were established by the Spanish in 1776 (Milliken et al. 2009:87) and
brought the most dramatic and permanent change to local Ohlone Life. The records kept by the missionaries indicate that the East Bay tribelets of Huchiuns had been baptized starting in 1777 and the first large group in 1794. Between 1794 and 1795, the East Bay Huchiuns and Saclans represented the largest mass movement of peoples to Mission Dolores (Milliken et al. 2009:103). This influx of people created a surge in mission population from 628 to 1,095 on the account of entire villages of people moving from the East Bay to the mission via tule boat (Milliken et al. 2009:103). Huchiuns and Saclans resisted the Spanish at Mission Dolores in the spring of 1795 and many Huchiun people returned to their villages in the East Bay. Resistance continued in 1797 as Mission Indians, led by Baja California native Raymundo Mornate, were driven out of Huchiun territory as they tried to conduct forced baptisms (Milliken et al. 2009:104).

The Spanish responded to the resistance in mid-July of 1797 by attacking and defeating the Saclan Bay Miwoks in the current day Lafayette area. The Spanish then raided Huchiun villages in the present day Richmond region (Milliken et al. 2009:104). The raids forced many of the fugitives from both tribes to rejoin the mission, but took the men they believed to be the leaders of the rebellion to the San Francisco Presidio for trial and punishment (Milliken 1995:164, 167-168).

**Mexican Period (circa 1822 – 1848)**

Richmond was a part of the San Pablo land grant that included 7,000 acres given to Francesco Maria Castro by the Mexican government in 1823, and was one of the first land grants made in Contra Costa County (Whitnah 1944:14-15). Francesco Maria Castro was born in the district of Soñora, Mexico. He served 13 years in the Mexican
Army, and retired a corporal in the Mexican Company of Artillery at the San Francisco Presidio. By 1830, the Castro family had established a homestead on the bank of Wild Cat Creek in the town of San Pablo. His second residence was the house known as the Alvarado adobe in the town of San Pablo (Whitnah 1944:15).

Don Castro died November 3, 1831 before the title to this land grant was finalized (Whitnah 1944:15). After his death, a title to the tract was contested resulting in court action that lasted a period of over 40 years, making it one of the largest and most celebrated land cases in the country at the time (Whitnah 1944:19). In March of 1894, the court decreed the lands to be divided among 148 owners, with Francesco Mari Castor’s heirs receiving about 200 acres (Whitnah 1944:19-20). The lands that were included in the 1894 decree would eventually be the sites of future industrial works such as the location of the Standard Oil Company’s oil refinery and Santa Fe Railroad’s shops and yards (Whitnah 1944:19).

American Period (circa 1848 – 1894)

In the first few decades after California gained statehood in 1850, Americans acquired large holdings in the Rancho San Pablo area including Ellis Landing, owned by Captain George Thomas Ellis. Ellis Landing was a shipping terminal and warehouse constructed a few years after 1849 and served as an important shipping point from San Francisco for many hay and grain farmers (Whitnah 1944:94). The landing was situated on a filled strip of waterfront property and would be the future location of Shipyards No. 2 for the Kaiser Shipyards (Whitnah 1944:94). The fill used for the landing reportedly
came from the prehistoric Ellis Shell Mound, located approximately two blocks north of the landing (Banks and Orlins 1981:5.6).

**Incorporation Period (circa 1894 – 1939)**

By the late 1900s, real estate development had begun on the Rancho lands once private ownership by the Castro family was nullified (Ramsey 1981:5.8). Development included the transformation of the landscape into blocks of uniform city lots that contained agricultural hamlets (Ramsey 1981:5.8). John Nicholl was among the first to promote the Richmond area as a major harbor city. On February 26, 1897, the San Francisco and San Joaquin Railway paid Nicholl $80,000 for a 57-acre parcel of land at and near Ferry Point at Point Richmond (Whitnah 1944:26). The site was to be the company’s western terminus that included railroad yards, shops, and a terminal for a transcontinental line. However, the San Francisco and San Joaquin Railway went bankrupt prior to competition of the project and sold the land to the Santa Fe Railroad (Whitnah 1944:32-33).

In 1902, the Standard Oil Company opened a refinery on purchased lands located on the west side of Potrero Hills and soon became the largest refinery on the West Coast (Whitnah 1944:37-44). The refinery produced 3,317,000 barrels of oil in the first year of its operation, or approximately 9,000 barrels a day. The refinery had operated under the name of Pacific Coast Oil Company, but changed its name to Standard Oil Company (California) in 1906 (Whitnam 1844:37).

The founding of the City of Richmond can be attributed to the work of Alfred Sylvester McDonald, who in 1902, along with several others, purchased a large 457.06-
acre property (Ramsey 1981:5.19). McDonald, a real estate investor, subdivided the property into business, commercial, and residential lots. McDonald filed a petition at the end of the 19th century with the Contra Costa County Board of Supervisors for an electric trolley franchise. Shortly thereafter, an electric trolley rail system was established from the Santa Fe depot at Point Richmond to the Southern Pacific Depot in San Pablo (Ramsey 1981:5.19-5.20). The City of Richmond officially became incorporated on August 6, 1905 (Whitnam 1944:39). By 1910, the United States Census Bureau had estimated the City of Richmond’s population contained 6,649 white residents, 29 black, and 124 categorized as either Indian, Chinese, Japanese, and all others (U.S. Department of Commerce and Labor – Bureau of the Census 1910).

Wartime Period (circa 1939 – 1945)

The Second World War catapulted the City of Richmond into becoming “one of the outstanding industrial and war production centers of the Pacific Coast” (Whitnah 1944:117). The expansion of Richmond during the 1940s included the construction of shipyard No. 1, followed by the three additional shipyards in the Richmond Inner Harbor, as part of the Kaiser Shipyards (Whitnah 1944:119-122; NPS 2014a). More than 747 vessels were built at the shipyards during the war, a production timeline that has not been equaled anywhere else in the world, before or sense (NPS 2014a). The construction of the shipyards had changed the city’s population from a little over 23,000 in 1940 to over 100,000 by 1943, as roughly 90,000 new workers were attracted to the shipyards (Whitnah 1944:119-123; NPS 2014a). The City of Richmond developed large-scale public housing to accommodate the swell of new workers. The housing program was the
“largest one of the country to be handled under the direction of a single Housing Authority” (Whitnah 1944:123).

The role that women played in the war effort was captured by “Rosie the Riveter” which became a cultural icon, and represented the women who worked in factories producing munitions and war supplies. The icon inspired a social movement in the United States that increased the number of working American women in defense industries and supportive services to 12 million during the war (NPS 2014b). In Richmond, 27% of the shipyards defense workers were women by the wars end. The shipyards invented a parallel term to “Rosie the Riveter” called “Wendy the Welder,” but it never received the icon status of Rosie (NPS 2014a). The Rosie the Riveter World War II Home Front National Park was opened in Richmond on October 14, 2000, and preserves and interprets the legacy of those workers (NPS 2014b).

In the following chapter, I provide an overview of the previous archaeological research that has been conducted on CCO-297. The chapter discuses archaeological studies that have spanned 100 years, beginning with Nels Nelson in 1905, and concluding with the most recent investigations by Alta Archaeological Consulting LLC in 2015.
Chapter 5. Background of Archaeological Research at CA-CCO-297

Introduction

The following chapter discusses CA-CCO-297 and three other prehistoric sites (CCO-298 through -300) that comprise the Stege Mound Archeological District. This information was partly compiled by archival research that is discussed in Chapters 6 and 7. The discussion of archaeological research conducted at CCO-297 is divided into three parts: (1) research performed from the years 1905 to 2011, (2) research performed between 2011 through 2012, and (3) research performed from 2013 through 2015. The archaeological excavations that occurred between 2013 and 2015 provided column and core samples that are used for analysis in this thesis. A review of the study area, scope of the archaeological excavations that occurred during the CRM project, and regulatory background are provided in Chapter 1.

Archaeological Research (1905 – 2011)

Nels Nelson from the University of California at Berkeley originally recorded the Stege Mound sites in 1905 during his survey of shellmounds along the tidal shores of San Francisco Bay (Nelson 1909; Arnold and Walsh 2010; DeGeorgey 2013). By 1915, many of the Stege Mounds were leveled during real estate development. L.L. Loud, also of U.C. Berkeley, was able to salvage some artifacts including charmstones, painted pestle, hammerstones, sinkers, bird bone whistles, and bird bone beads, during his evaluations of the shellmounds (Loud 1924). The surface extent of CCO-297 was compared to mound no. 298 (CCO-298) by the area of the shell scatter and measured 73
m east-west by 48 m north-south (Loud 1924:357-358). Loud describes CCO-297 as being leveled by the time of his investigation, and notes the proximity of the site to a small salt-water slough:

Mound no. 297. Another shellmound, leveled before 1915, was situated in the Owens addition, across a small salt-water slough, two or three hundred feet north of mound no. 300. To judge from the scattered shell, it possibly covered nearly as much area as no. 298, though probably not as deep (Loud 1924: 358).

During World War II, the Stege Mounds were located in an area that was part of the Richmond Shipyard Complex used for parking and storage and covered with 0.6 to 2 m of rock landfill. These alterations were followed by the construction of a drainage ditch that destroyed a portion of the eastern half of CCO-297. The accumulation of these alterations resulted in the location of CCO-297 being lost until 1979 (Banks and Orlins 1981:7.26; DeGeorgey 2013: 24-26).

On June 25, 1979, Peter Banks and Bob Orlins of California Archaeological Associates (CAA) were retained by the City of Richmond to conduct cultural resource investigations for the Richmond Harbor Redevelopment Project 11-A (Banks and Orlins 1981:1.2). Project 11-A comprised of approximately 965 acres and included the development of a 2,000 berth marina for small boats, 2,000 – 4,000 residential units, commercial uses, and space for public recreational use. One-third of the project area was located below, or within, the intertidal zone (Banks and Orlins 1981:1.1). The cultural resource investigations identified eight prehistoric resources within the project area that included CCO-297. In attempting to relocate the location of CCO-297, Banks and Orlins used the reference points of the known location of CCO-300, the location of the slough around the Stege Mounds, and the primary document of a 1912 General Plan map to
estimate the site’s approximate location. These sources revealed the site to be near Pierson Avenue and Meeker Ditch. Surface reconnaissance, coupled with exploratory subsurface auguring, confirmed the location of CCO-297 (Banks and Orlins 1981:7.8-7.9).

Further cultural resource investigations conducted by Banks and Orlins at CCO-297 consisted of subsurface testing with 29 power auger units and 14 hand auger units. The testing resulted in defining the site’s surface boundaries to 100 m north-south by 70 m east-west (Banks and Orlins 1981:7.26). Subsurface deposits of intact shellmidden were encountered beneath 0.3 to 1 m of landfill. The intact midden consisted of 0.5 to 2 m of undisturbed cultural deposits, and the landfill deposits overlaying the site averaged 55 cm in depth (Banks and Orlins 1981: 7.30-7.37).

Excavation of three test units took place at CCO-297 to evaluate the site’s eligibility to the NRHP. A total of 7.4 m³ were excavated, washed through 3 mm or 6 mm mesh screens, and processed (Banks and Orlins 1981). Their excavations recovered disarticulated pieces of human bone consisting of three cranial fragments, one pelvis fragment, and two molars. Other resources identified include three cooking features, 10 clamshell disk beads, 11 small-serrated projectile points of Napa Valley obsidian, 38 bone or antler tools, 30 lipped and whole *Olivella* shell beads, a magnesite disc bead, and groundstone tools (Banks and Orlins 1981; DeGeorgey 2013; Eerkens 2014). The artifact assemblage, supported by 14 radiocarbon dates from those materials, show that CCO-297 is a single-component site attributed to Late Phase 2 of the Augustine Pattern,
dating from 1370-1700 AD (Banks and Orlins 1981: 5-6; DeGeorgey 2013: 26; Eerkens et al. 2014: 25).

An intact prehistoric human burial, along with funerary objects, was uncovered during the 1985 construction monitoring of culverts along the Meeker Ditch (Banks and Orlins 1981:7.29). The burial was determined to be male, from 20 to 30 years of age. Bone pathology indicated the individual had a severe case of Bejel, a form of endemic syphilis that manifested as lesions on bone. The funerary objects included 192 small-lipped *Olivella* shell beads (Banks 1985: site record), characteristic of Phase 2 of the Late Period (DeGeorgey 2013: 26).

**Archaeological Research (2011 – 2012)**

From 2011 to 2012, North Coast Resource Management – under the direction of Alex DeGeorgey – conducted archaeological investigations at CCO-297 for the Marina Bay Grade Separation Project. Investigations included recovery excavations on portions of the site affected by construction on an existing compressed natural gas line by the Pacific Gas and Electric Company (DeGeorgey 2013:1).

The data recovery analyzed approximately 81.1 m$^3$ of shellmidden. Six m$^3$ were analyzed by hand excavations and 75.1 m$^3$ analyzed by screening (DeGeorgey 2013; Eerkens et al. 2014). The recovery of material from the excavations included an “extensive disturbed cultural deposit under the Marina Bay Parkway” and “yielded a large assemblage of prehistoric material” (DeGeorgey 2013:1). Materials recorded include food refuse, stone and shell beads, projectile points, bone awls, bird bone
whistles, flute tubes, magnesite, steatite, and travertine beads, charm stones, baked clay basketry impressions, and other artifacts (DeGeorgey 2013:1; Eerkens et al. 2014:25).

The combination of absolute and relative dating of cultural material collected provided evidence that CCO-297 is a single-component site that was occupied for about 250 years during Phase 1c, Phase 2a and possibly Phase 2b of the Late Period (1450 to 1700 cal AD) (DeGeorgey 2013:247). Absolute dating of the material included 12 radiocarbon dates from human bone, clamshell disk beads, and *Olivella* beads, and 94 hydration rim values. Rosenthal’s (2005) hydration rates were used in correlating hydration rim values to age estimates. Relative dates of over 700 temporally diagnostic artifacts, including lipped *Olivella* beads, clamshell disk beads, and Stockton serrated and small corner-notched projectile points, were consistent with the radiocarbon and obsidian hydration measurements (DeGeorgey 2013:247; Eerkens et al. 2014:25-27).

Artifacts recorded at the site including notched net weights, mortars, pestles, and projectile points, indicated subsistence activities comprised of fishing, fowling, sea otter hunting, and clamming. The artifacts were noted to reflect “fairly low-ranked, small-bodied, and processing-intensive foods” (Eerkens et al. 2014:28), consistent with models of resource depression in the Late Period in San Francisco Bay. The analysis of shellfish collected identified *Macoma nasuta* (bent-nosed clam) – a species that inhabits bay/estuaries – comprised 80.2% of collection. This inferred that “the inhabitants of CCO-297 were heavily reliant on clam beds within the tidal marshes and mud flats adjacent to the site” (DeGeorgey 2013:205).
Stable isotope analysis performed on shellfish remains suggested that foraging for *Macoma* shells occurred mainly during early summer and early winter, with almost no evidence of clamming occurring during the late winter and early spring (Eerkens et al. 2014:41). The seasonality of shell procurement is attributed to settlement patterns where families, or parts of the population, disperse to other localities in the late winter and spring when few plant resources are available, and disperse again in late summer and fall to harvest plants when they are in abundance (Eerkens et al. 2014:42). Peak times for clamming would occur in late fall and early winter when plant productivity decreased in the surrounding areas, and early summer when days are longer and not all of the plants had ripened (Eerkens et al. 2014:42).

Paleobotanical and vertebrate faunal analysis indicated CCO-297 was occupied throughout the year, with hunting and gathering occurring in a range of seasons. Analysis of charred plant remains suggested a seasonality of collecting nuts in the fall, and a smaller percentage of small seed collecting occurring in the spring and summer (Wohlgemuth and Tingey 2013:203). Faunal analysis indicated that hunting for specific game occurred in various seasons. Waterfowl were hunted in fall through early spring, harbor seals in the summer, and elk and deer were primarily hunted in the winter and spring (Simons 2013:185).

In conclusion, the analysis of data sets collected during the 2012-2013 fieldwork addressed five research topics including cultural chronology, settlement system, subsistence strategy, trade and exchange systems, and paleoenvironment (DeGeorgey 2013). The research established CCO-297 as a large sedentary village located near the
shoreline and was occupied for approximately 250 years during Phase 1c, 2a, and 2b of the Late Period. The investigations contributed to CCO-297 being one of the best dated and well-defined single component sites located on the San Francisco Bay shore (DeGeorgey 2013:248-249; Eerkens 2014:27).

**Archaeological Research (2013 – 2015)**

Alta Archaeological Consulting LLC (ALTA) conducted additional investigations at CCO-297 from 2013 to 2015 under the supervision of Alex DeGeorgey (Figure 3). CRM investigations for the Marina Bay Grade Separation Project included archaeological excavations of 165 control units, with 119.9 m³ of artifact-bearing sediments exhumed.
Control units were placed in areas where development of the Grade Separation Project would affect undisturbed portions of CCO-297. This included the placement of a sewer line trench, drain inlet trench, retaining wall, and deep soil mix test piles. The CRM investigations during 2013-2015 collected and analyzed vast amounts of information from a wide range of datasets. The findings of the investigations are currently being compiled (DeGeorgey 2015).

Philip Kaijankoski and Jack Meyer (2015) from Far Western Anthropological Research Group, Inc. were retained by ALTA to conduct geoarchaeological research at CCO-297. Research methods used at the site consisted of documenting exposures in construction trenches and archaeological units, in addition to drilling and documenting three hand auger samples from archaeological units. The column sample used in this thesis research is the same one analyzed in the field by Kaijankoski from a control unit in the DI 25 trench.

Stratigraphic units were identified by physical composition, superposition, relative soil development, and/or textural transitions characteristic of discrete depositional cycles (Kaijankoski and Meyer 2015). The investigation documented seven distinct stratigraphic units that include from youngest to oldest: artificial fill (Stratum I), redeposited shell midden (Stratum II), intact shell midden (Stratum III), laminated shell and estuarine deposits (Stratum IV), wetland deposits (Stratum V), channel deposits, (Stratum VI) and, a truncated ancient landform (Stratum VII). Each stratum was designated a master horizon number by use of upper-case letters. Lower case letters were used to describe subordinate soil horizons.
Kaijankoski and Meyer (2015) concluded that CCO-297 was formed upon a single stratigraphic unit (V) that was deposited within a wetland environment throughout the majority of the Holocene. The wetland environment transitioned into a terrestrial landform that was likely due to loss of freshwater input and/or infilling with sediments around 2000 years ago (2015:375). The waters of the San Francisco Bay are described as having appeared to reach CCO-297 sometime after 1000 cal BP based on Meyer and others (2013) sea-level curve for the San Francisco Bay Area, as well as other lines of evidence. The recent sea-level curve is based on the age and elevation of radiocarbon dates on marsh deposits from around the region. Their research, along with radiocarbon dates from the recent Stege Mound investigations and other collected data, allowed them to reconstruct the timing when sea-level rise occurred at 1000-year increments, and when they likely reached CCO-297.

The position of these shorelines was determined through a reconstruction of the “pre-Bay” landscape that existed prior to being inundated by rising sea levels during the Holocene. While this surface was submerged it was covered by sediments deposited within the newly established estuary, known collectively by geologists as the younger bay mud. To reconstruct the surface topography of this inundated landscape, the thickness of younger bay mud as mapped by Goldman (1969) was combined with modern elevation data derived from 1/3-arc second National Elevation Dataset (USGS 2009) to create a digital elevation model. The contours in the 2009 bay mud thickness digital dataset (Goldman 1969) were corrected against the original map (Goldman 1969) to identify and remove discrepancies from the original. The elevation of paleo-shorelines at 1000 year increments were then generated from the Bay Area sea level curve (Meyer et al. 2013) and projected onto this “pre-bay” landscape (Kaijankoski and Meyer 2015:373).

Stratum IV is noted as containing cultural shell and appears to have been reworked in the tidal zone by 525 cal BP. This cultural deposition of shell likely built up the elevation of the ground surface, thus allowing the later inhabitants to occupy some small areas on the northwest portion of the site that were previously tidal environments.
(Kaijankoski and Meyer 2015). Stratum VII maybe associated with pre-Holocene alluvial deposits, indicating that “Wildcat Creek, or a distributary thereof, once flowed far to the south of its current location” and “tectonic activity might have ‘beheaded’ the main channel, causing it to shift across the Wildcat Creek fan to its present position” (Kaijankoski and Meyer 2015:371). Wildcat Creek may have been the source that provided the paleo-channel alluvial deposits observed in Stratum VI.

Radiocarbon Dating

Radiocarbon samples submitted for testing aided in establishing the time span of site occupancy at CCO-297. Forty-four samples were selected for radiocarbon dates that included 12 from Banks and Orlins’ (1981) investigation (DeGeorgey 2015). Samples selected from the 2011 through 2015 investigations were calibrated using the CALIB 7.0 program (Stuiver and Reimer 1993). Calibration for the marine radiocarbon reservoir effects is important because marine organisms often receive inconsistent radiocarbon dates due to different levels of carbon 14 found in oceans and other bodies of water (Beta Analytic 2015).

Calibrated material included *Macoma nasuta* shells that were calibrated using a marine reservoir correction of 320+/-30, which is the mean for San Francisco Bay Estuary *Macoma nasuta* (Ingram and Southon 1996:575). Clamshell disk beads were calibrated using a Bolinas Bay marine reservoir correction of 232+/-25 (Robinson 1981). Olivella shell was calibrated using the Groza et al. (2011) marine reservoir correction of 260+/-35, which was developed specifically for *Olivella* in the Central California region. Human bone samples were calibrated using a mean San Francisco Bay Estuary marine
reservoir correction of 365+/−35 (Ingram and Southon 1966:575). Radiocarbon dates taken on cultural deposits show occupation of the site occurred from 1350 to 1800 cal AD. Seven of these radiocarbon dates – four taken from the DI 25 trench and three from the SLT trench – are used in this thesis research and are provided in Table 1 and Appendix G.

Table 1. Summary of radiocarbon dates from CA-CCO-297 used in this thesis.

<table>
<thead>
<tr>
<th>Lab No.</th>
<th>Unit/Location</th>
<th>Level depth</th>
<th>Description</th>
<th>Conventional Radiocarbon Age (Years BP)</th>
<th>Calibrated Age Range (2-Sigma) with Relative Area Under Probability Distribution</th>
<th>Calibration Curve</th>
<th>Delta R</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-AMS 005229</td>
<td>DI25 S1/E1.5</td>
<td>185</td>
<td>Shell from Charcoal Lens 3 (CL#3)</td>
<td>870+/−24</td>
<td>1708-1910 (0.896) Cal AD 1920-1950 (0.102) Cal AD</td>
<td>MARINE13</td>
<td>365+/−35*</td>
</tr>
<tr>
<td>D-AMS 005230</td>
<td>DI25 S1/E1</td>
<td>205</td>
<td>Shell from Charcoal Lens 4 (CL#4)</td>
<td>955+/−30</td>
<td>1619-1882 (1.000) Cal AD</td>
<td>MARINE13</td>
<td>365+/−35*</td>
</tr>
<tr>
<td>D-AMS 005232</td>
<td>DI25 S1/E0.2</td>
<td>230</td>
<td>Shell from Charcoal Lens 5 (CL#5)</td>
<td>1069+/−26</td>
<td>1505-1680 (1.000) Cal AD</td>
<td>MARINE13</td>
<td>365+/−35*</td>
</tr>
<tr>
<td>D-AMS 005228</td>
<td>DI25 N0/E5</td>
<td>300</td>
<td>Peat/Soil from Auger Core</td>
<td>854+/−24</td>
<td>1058-1064 (0.007) Cal AD 1068-1072 (0.004) Cal AD 1154-1254 (0.988) Cal AD</td>
<td>IntCal13</td>
<td></td>
</tr>
<tr>
<td>BETA 359081</td>
<td>SLT48</td>
<td>286</td>
<td>Wood</td>
<td>520+/−30</td>
<td>1324-1345 (0.109) Cal AD 1336-1403 (0.892) Cal AD</td>
<td>IntCal13</td>
<td></td>
</tr>
<tr>
<td>BETA 359082</td>
<td>SLT48</td>
<td>340-320</td>
<td>Soil</td>
<td>6010+/−30</td>
<td>4991-1830 (0.987) Cal BC 4813-4807 (0.013) Cal BC</td>
<td>IntCal13</td>
<td></td>
</tr>
<tr>
<td>BETA 3590823</td>
<td>SLT48</td>
<td>480</td>
<td>Soil</td>
<td>10150+/−40</td>
<td>10118-9797 (0.986) Cal BC 9788-9768 (0.014) Cal BC</td>
<td>IntCal13</td>
<td></td>
</tr>
</tbody>
</table>


Drain Inlet 25 Trench

This section focuses on the drain inlet trench (DI 25) that was archaeologically excavated from January 6 through January 15, 2014. Data extracted from soil and
sediment samples collected from this trench are analyzed and discussed in Chapters 6, 7, and 8. DI 25 consisted of a trench for the installation of a storm drain inlet box and 58.42 cm drainpipe. Intact shell midden was exposed during archaeological monitoring of mechanical excavation. The trench was divided into seven 1 by 1 m control units and an arbitrary grid was established with north aligned to 5° (true north). Unit designations were based on grid coordinates and the depth elevation measured was taken below Datum 1 (DeGeorgey 2015). The trench measured 7 m in length and 1 m in width, increasing in depth from 230 cm below Datum 1 (cmbd1) along the eastern extent, to 280 cmbd1 along the western extent.

Figure 4. Field sketch of Feature 38.
Traditional archaeological methods used in the trench included hand excavation by shovel and trowel. A sump pump was installed in unit N0/W1 to dewater the unit and allow excavation to continue below the water table. Midden soil collected during the excavation was wet screened through 6mm steel mesh. An 8.89 cm bucket auger was used to gather sediments situated below N0/E4, and were used in the analysis of this thesis as well as geoarchaeological investigations previously discussed. A vertical column sample of shell midden was extracted from the southern profile of unit N0/E4 for this thesis research. The analysis of both core and column samples are discussed in Chapters 6, 7, and 8.

The archaeological excavations of DI 25 unearthed an array of cultural materials including A and E series *Olivella* beads, *Haliotis* pendants, Stockton serrate and other flaked projectile points, obsidian bifaces, chert and obsidian debitage, various groundstones including a mortar and milling slab, baked clay, and modified bone tools (DeGeorgey 2015). Features recorded in DI 25 include Feature 38, a rock heap consisting of groundstone, heat altered rock, bone, and charcoal fragments (Figure 4).

Features 40-44 consist of a series of burned soil layers and are apparent in the soil profile. The burn features are composed of a thin, dark, carbon-rich layer situated on top of a thick band of thermally-altered shell midden. Each burn event appears quite large and covers an expansive area. These features portray the overall oval shape of the mound (Figure 5), where the angle of burn layers are near level in lower depths, but increase in upper portions of the profile (DeGeorgey: 2015).
Five of the seven strata identified at CCO-297 by Kaijankoski and Meyer (2015) were present in the DI 25 trench. These include Stratum I (Ap1), Stratum II (Ap2), Stratum III (3Au), Stratum IV (4Ac), and Stratum V (5Ag and 5Cg). Stratum I consists of modern road and fill material, while Stratum II (Ap2) consists of shell deposits that were completely disturbed during historic times. Stratum III (3Au) is intact shell midden with high frequencies of large or whole shell (DeGeorgey: 2015:83).

Stratum IV (4Ac) is a discrete layer of laminated shell and marsh deposits indicating periodic flooding or inundation of the site occurred during its earliest occupation (DeGeorgey 2015). Organic sediments taken from this stratum in the SLT trench returned a radiocarbon date ranging from 1393 to 1443 cal BC (BETA-359081; 2-sigma intercept 89.2%). The upper part of the stratum consists of an approximate 10 cm
thick band of fine grain marsh deposits with no cultural material, while the lower layer contains 5 cm of marine shell and cultural material. Stratum V (5Ag) was identified as black marsh deposits that formed in a freshwater wetland environment. A sample from this stratum returned a radiocarbon date of 1154 to 1254 cal AD (D-AMS 005228; 2-sigma intercept 98.8%). The layer directly below contains a gleyed parent material (5Cg) that formed during the Pleistocene-Holocene transition. Organic sediments taken from Stratum V (5Cg) in the SLT trench returned radiocarbon dates ranging from 4991 to 4830 cal BC (BETA-359082; 2-sigma intercept 98.7%) at the 340-350 cm bd2 depth, and from 10,118 to 9797 cal BC (BETA-359083; 2-sigma intercept 98.6%) at the 480 cm bd2 depth.

In the following chapter, I present the materials and methods used in the current study. First, I describe the methods used in obtaining preliminary information pertaining to the research area. The chapter then describes the fieldwork techniques used at CCO-297 that includes the extraction of column and core samples. Lastly, the chapter describes the laboratory procedures that were employed to obtain data from the column and core samples.
Chapter 6. Methods

Introduction

This chapter details the methods used to obtain geoarchaeological data with the goal of placing CCO-297 into a temporal, spatial, and prehistoric landscape context. A diachronic reconstruction of the dynamic elements of the paleo-landform was achieved by collecting data from primary historic sources, as well as field-based and laboratory techniques commonly used in geoarchaeological investigations. Preliminary research included a literature and records search conducted at the Northwest Information Center (NWIC) of the California Historical Resources Information System. Other references used to interpret the landscape on a regional scale include satellite images, aerial, topographic, and geological maps. Field-based techniques include excavating, recording, and collecting of column and core samples. Laboratory methods include loss on ignition, magnetic susceptibility, soil phosphorus, potential of hydrogen, macrofossil, and microfossil analysis. The combination of preliminary data collection, fieldwork, and accompanying laboratory procedures allowed for a holistic variety of data sets.

Regional-Scale

A records search conducted at the NWIC (File # 14-0900) involved analyzing previous cultural resource and archaeological investigative reports of the study area. The archival search indicated four studies had taken place at CCO-297 that spanned from 1924 to 2013 (Loud 1924; Banks and Orlins 1981; Busby and Nissen 1974; DeGeorgey 2013). The findings of these reports are discussed in the previous chapter.
Topographic maps consulted include the USGS 7.5-minute series Richmond Quadrangle maps from 1959 (photo-revised 1980) and 1947. USGS 15-minute series maps included the San Francisco Quadrangle maps from 1895 and 1915. Other historic maps consulted include a Coast Survey Map (Harrison 1853), and a Sale Map of Salt Marsh and Tide Lands (Allardt 1872). USDA (2014) and UC Davis (2014) provided electronic soil maps of the study area. Aerial and satellite images were provided by Google Earth (2014). Applications form the Google Earth Library allowed the layering of a georeferenced USGS 15-minute San Francisco Quadrangle map from 1915 with Google Earth satellite and aerial images. The USGS National Map Historic Quadrangle Scanning Project provided the scanned topographic maps.

Field Methods

Field investigations were performed in January 2014, and include excavation of the DI 25 trench, recording a segment of CCO-297’s stratigraphic profiles, and extracting a soil column and a sediment core sample for laboratory analysis. Cultural soils and native sediment samples were extracted from within and below the DI 25 trench. The trench measured 7 m in length and 1 m in width, increasing in depth from 230 cmbd1 along the eastern extent, to 280 cmbd1 along the western extent. Intact shell midden was exposed during archaeological monitoring of mechanical excavation. The trench was divided into seven 1 by 1 m control units and hand excavated using shovel and trowel. Excavated midden soil was wet screened through 6mm steel mesh.
A vertical column sample of shellmidden was extracted from the southern profile of control unit N0/E4. The column sample measured approximately 15 by 15 cm, and ranged in depth from 165 to 230 cm bd1. The column sample was extracted by hand, with a trowel, in approximately 5 cm increments. Sediments were placed in plastic containers, labeled with provenience information, photographed with a digital camera, and retained for laboratory analysis.

A core sample of the site’s cultural soils and underlying native sediments was extracted within the eastern control unit N0/E5. An 8.89 cm hand driven bucket auger was used to extract the core sample. The total length of the core was 245 cm and ranged in depth from 230 to 470 cm bd1. Sampling was conducted in 20 cm intervals, which was the maximum amount of material the auger barrel could contain during a single extraction. Fluid resistance between the auger and water occurred when extracting core samples below the water table (~252 cm bd1 depth). This resistance made it physically difficult to extract the auger at lower depths. Coring was terminated at the 470 cm bd1 depth due to physical limitations. Soil samples were placed on a tarp, labeled, photographed, wrapped in plastic, and stored in plastic containers for future laboratory analysis.

Once archaeological excavations were complete, the entire southern sidewall profile of the DI 25 trench was extensively photographed and a soil profile was drawn to record the exposed cultural and natural stratigraphy (Figure 6).
Figure 6. Stitched photographs (bottom) and southern wall profile sketches (top) of the D1 25 Trench showing mound stratigraphy and where column and core samples were extracted.
Laboratory Methods

A series of laboratory methods that are currently used in geomorphic and geoarchaeological investigations was conducted on the samples. These include LOI, magnetic susceptibility, soil phosphorus, pH, and macrofossil analysis (Jones 2007; Goman et al. 2008). Laboratory work was conducted at the Department of Anthropology’s David A. Fredrickson Lab and the Department of Geography and Global Studies’ Quaternary Lab (SQUAL) located at Sonoma State University.

Loss on Ignition

Figure 7. Crucibles from LOI testing after two hours in 950° C furnace.
Loss on ignition (LOI) testing is an inexpensive and widely used method used to establish the percentage of organics, inorganics, water, and calcium carbonate content within soils and sediments (Dean 1974; Heiri et al. 2001; Veres 2002; Goman 2005). This technique can be an accurate way of documenting fluctuations between sediment accretion and plant growth in depositional environments such as estuaries (Jones 2007:22). The LOI process consists of weighing samples before and after heating of the material at specific temperatures and durations in an oven and muffle furnace to record weight loss.

In this study, the LOI process began by dividing the column and core samples into 5 cm increments (57 samples in total). A 10 mL sample, or five teaspoons of soil or sediment, was then placed into a pre-weighed crucible, weighed on a scale (precise to 0.001 g), recorded again, and then placed in an oven for 24 hours at 105° C to remove any moisture. After a 24-hour period, the crucibles were removed and placed in a sealed glass desiccator to cool down, and then reweighed to establish moisture loss. This process of weighing and reweighing the same crucible samples was then repeated in a muffle furnace several more times, once for two hours at 550° C, and then at 950° C for two hours (Figure 7). The LOI for establishing water, organics, inorganics, and carbonates was then calculated using the following equations (cf., Heiri et al. 2001):

1. Percent water: $\frac{(WS-DW_{105})}{WS} \times 100$
2. Percent organics: $\frac{(DW_{105}-DW_{550})}{DW_{105}} \times 100$
3. Percent inorganics: 100 - % Organics
4. Percent carbonate: $\frac{(DW_{550}-DW_{950})}{DW_{105}} \times 100$
In these equations: C = crucible weight; WS = wet sample weight – C; \( \text{DW}_{105} \) = dry weight of the sample after 24 hours in the oven at 105°C – C; \( \text{DW}_{550} \) = dry weight of the sample after combusting off organic carbon at 550°C for 2 hours – C; \( \text{DW}_{950} \) = dry weight of the sample after combusting off calcium carbonate at 950°C for 2 hours.

**Magnetic Susceptibility**

Magnetic Susceptibility (MS) testing measures the degree that a soil or sediment sample is magnetized in the presence of a magnetic field by detecting magnetic minerals within the sample (Thompson and Oldfield 1985; Jones 2007; Rosendahl et al. 2014; Gale and Hoare 1991). MS testing is used in geoarchaeological site formation studies because the magnetism of soils can be greatly affected by anthropogenic activities such as the burning or heating of material and/or repeated dumping of organic waste (Jones 2007:22; Goman et al. 2010:3; Cook and Burks 2011:150; Rosendahl et al. 2014:22). This testing can help define soil development processes, buried cultural layers, and “provide information on human impacts and how site features form and change, revealing variation in sediment input from cultural or natural processes” (Rosendahl et al. 2014:22).

MS testing can also be used to show the development of marshes by detecting a decline of mineralogical material that coincides with marsh accretion and organic evolution (Goman et al. 2008:1133).

Preparing the column and core material for MS testing began by segmenting the samples in 5 cm increments (57 samples in total). The individual samples were tightly packed in 10 cc plastic vials free of air pockets and capped. The plastic vials were placed into the holder of a Bartington MS2 meter and a magnetic reading was made using the
International System of Units (SI) option. Three readings were taken on each sample, and the average of the three values was calculated and recorded.

**Phosphate**

![Figure 8. Phosphate samples.](image)

The testing of soil phosphate in archaeology is relevant because phosphate is one of the most common compounds added to soils by human activities, along with calcium and nitrogen (Edit 1977:203). Past human activities can be detected by phosphorus analysis because phosphate “becomes fixed rapidly on deposition in most soils” and “is a relatively stable compound compared to other elements within the soil system and is largely resistant to leaching” (Jones 2007:17). Phosphorus in an archaeological context is attributed to human or animal excreta, burials, building materials, and refuse or food processing areas (Jones 2007:17).
Testing for soil phosphorus in this study used the “spot test”, a simple and low-cost chemical testing (Schwartz 1967; Edit 1973; 1977). First, the column and core samples were segmented into 5 cm increments (57 samples in total). Next, two solutions were prepared. Solution A consisted of 5 g of ammonium molybdate dissolved in 100 mL of distilled water, and then acidified by adding 30 mL of 5N hydrochloric acid. Solution B contained 1 g of ascorbic acid dissolved in 100 mL of distilled water.

The test involved placing a small amount of soil/sediment (~ 1 g) onto ash-free filter paper. Two drops of Solution A was applied and after 30 seconds two drops of Solution B was applied. If phosphate was present in the sample, then a blue color developed on the paper. A stronger hue is associated with more phosphorus content (Figure 8). After two minutes the samples were immersed in a solution of sodium citrate (a water to sodium citrate ratio of 2:1) to stop the reaction (Edit 1977:1329). The intensity and size of the color spot was recorded and given a number value 0 through 5, with 5 being the highest and most intense color and spot diameter. This grading system is a variation of classifications developed by Schwarz (1967) and Edit (1977). The samples were then labeled, photographed, and archived.

**Potential of Hydrogen**

The potential of hydrogen (pH) testing of soil/sediments is a measure of the deposits acidity or alkalinity and can help explain “aspects of taphonomy and artifact or ecofact preservation” (Jones 2007:22). Testing for pH in archaeology has been used to supplement visual recordings of stratigraphic interpretation in midden accumulations where stratigraphic zones are not otherwise visible (Deetz and Dethlefsen 1963:242).
Soil pH has also been associated with artifact and bone preservation, and “can be a very strong predictor of preservational state” (Gordon and Buikstra 1981:569).

In this study, 10 samples were systematically chosen because they represented a proportionate range of the depths and deposits along the column and core. This study originally tested 57 samples for pH, but it was later discovered the pH meter was faulty and gave inaccurate readings. The test was redone using a smaller sample size and a different pH meter. Each air-dried sample was weighed to 15 g and mixed with 45 mL of distilled water in a beaker. The samples were agitated by repeatedly stirring and left for at least 24 hours to soak. After the material soaked, a pH value of the solution was taken using a calibrated Hanna Instruments HI 99121 Direct Soil pH meter, just above the settled material, and recorded.

**Macrofossil**

Macrofossil analysis on archaeological materials too small to be caught in traditional screens, such as seeds, has been used in floatation techniques since the 1960s (Struever 1968). Similar to the floatation method, the capturing, and studying of macrofossils is frequently used in wetland and estuarine reconstruction (Brush and Davis 1984; Goman and Wells 2000; Goman et al. 2008; Dick et al. 2009). Macrofossil studies on core samples from the San Francisco Bay indicate that seeds encapsulated within the subsurface sediment represent local standing vegetation from the estuary marshes (Goman 2001: 407). Furthermore, marsh vegetation is zonal, and each zone (e.g., low, middle, and high) can be described by specific species of plants that compose those areas
In preparing the macrofossil analysis, samples from the column and core were taken at 5 cm intervals totaling 57 specimens. The methods used in the testing followed similar procedures by Whitlock and Larsen (2001) and Goman et al. (2008). Soil volume was established by using the water displacement method. A 1,000 mL cylinder was filled with 200 mL of water and soil was added until the beaker read 215 mL (approximately 15-20 g of soil or sediment). This was then placed into a 500 mL labeled beaker. Approximately 50 mL of sodium hexametaphosphate mixed with tap water was added as a dispersant to the beaker, stirred, and let rest for at least 24 hours.

After resting, the samples were then washed through a series of nested sieves. Mesh sizes of 1mm, 500 µm, and 125 µm were used on all 57 samples, while 250 µm, 125 µm, and 63 µm were used on a selected 13 subsamples to test for foraminifera fossils.
The caught material was then collected on a petri dish and analyzed under a 10x magnification dissecting microscope. Seeds observed under the microscope were counted, collected, and identified when possible using seed atlases and keys (Martin and Barkley 1961; Goman 2001; GIA 2006; Calflora 2014). Charcoal fragments were counted and recorded. When a sample contained a large amount of charcoal fragments their numbers were roughly estimated by the amount present in a 6 mm$^2$ area, and calculated using the dimensions of the petri dish ($<100$ mm$^2$). Foraminifera fossils were recorded as being either present or absent in a sample. Identification of foraminifera species was provided by Dr. Scott Starratt and Dr. Mary McGann of the US Geological Survey (personal communication 2014). Seed and foraminifera fossils were photographed using a Dino-Lite digital microscope camera, and then placed in plastic vials for archiving (Figure 10).

**Figure 10.** Foraminifera species *T. inflata* observed in macrofossil testing.
Microfossil

Dr. Scott Starratt of the US Geological Survey analyzed five sediment core samples taken at various depths (280-285, 305-310, 325-330, 345-350, and 385-390 cmbd1) for siliceous microfossils. Smear slides were made using Naphrax (r = 1.71). Ten transects were scanned on each slide. All slides contained poorly to moderately well preserved microfossils, a preservation that is consistent with marsh deposits from around the San Francisco Bay (Appendix F).

In the following chapter, I describe the results of the data analyses and provide interpretations of the findings. The data interpretations are based on archaeological and geoarchaeological lines of evidence. They explain site formation processes of CCO-297 in relation to a reconstructed paleoenvironment, and their correlation to environmental change along the San Francisco Bay estuary.
Chapter 7. Results and Interpretation

Introduction

This chapter provides results and interpretations of data obtained by the methods described in the previous chapter. Data analyzed from maps and images provides a spatial context for CCO-297, depicting its evolution on the landscape from historic to the present time. Data analyzed from the column and core samples are divided into three distinct zones. These zones reflect the evolution of a tidal marsh paleoenvironment and its direct correlation to the formation of CCO-297. In determining zonation, a series of quantitative and qualitative analyses was performed on the cultural and natural deposition within, and below, CCO-297. Figures 11, 12, and 13 provide a synthesis of these findings. All data gathered from macrofossil, LOI, MS, phosphate, and pH testing is compiled in an Excel database, presented in Appendixes A through E. Radiocarbon and microfossil results are presented in Appendixes F and G.

Regional-Scale

A review of historic maps of the study area indicates CCO-297 was positioned on the edge of a tidal creek that became incorporated into development projects in subsequent years. The 1853 Coast Survey map (Harrison 1853) indicates CCO-297 was probably located on the northern edge of a meandering tidal creek, situated in a marsh that extends southward towards the bay. A natural feature, presumably a freshwater pond, is located west and close to the site. By 1872 (Allardt 1872), the location of
Figure 11. Summary diagram for column and core samples of CCO-297 representing age, zonation, LOI, MS, and phosphate stratigraphy.
Figure 12. Summary diagram for column and core samples of CCO-297 representing age, zonation, and macrofossil stratigraphy.
Figure 13. Summary diagram for column and core samples of CCO-297 representing age, zonation, diatom, and foraminifera presence in stratigraphy. Note: sampling not continuous.
the freshwater pond is depicted as an orchard. The 1895 USGS 15-minute San Francisco Quadrangle map depicts the tidal creek extended farther northward than the 1853 map. Encroaching development is shown nearby that includes the Southern Pacific Railroad and several buildings. The 1915 USGS map depicts the tidal creek still being present, but by 1942 the creek has disappeared and is replaced by landfill containing roads in grid formation, most likely as an area slated for future development. The 1942 map shows the tidal shore now extends approximately .80 kilometers south, constructed from landfill. A segment of the Southern Pacific Railroad is depicted as being situated approximately 65.5 m north of CCO-297.

A precise location of the site was established by overlaying the 1915 USGS quadrangle map with georeferenced satellite images provided by Google Earth. Using the georeferenced maps as a guide, the landform of the pond depicted in the 1853 Coast Survey Map would have been located about 150 m west of CCO-297. The tidal shore of the bay would have been located about 325 m southwest of the site in 1915.

Depositional Zones

Zone 1: Cultural Deposits

Zone 1 (165-285 cmbd1) is characterized by anthropogenic soils composed of intact shell midden deposits containing five possibly heat-altered deposits (Feature 40 – 44) and five charcoal lenses. The current water table was encountered at a depth of 252 cmbd1. This layer is intact shell midden deposits and correlates with Stratum III (3Au) (Kaijankowsi and Meyer 2015) dating from 1350 to 1770 cal AD. A laminated stratum
measuring 15 cm thick – designated Stratum IV (4Ac and 4Ag) – contains mixed shell and organics and was recorded in three samples ranging from approximately 265 to 280 cm bd1 in depth. The laminated stratum consists of an approximately 10 cm thick band of fine grain marsh deposits with no cultural material or marine shell present. The lower layer of the laminated stratum measures approximately 5 cm thick and is a band of fine crushed marine shell and prehistoric artifacts. A radiocarbon sample from this stratum returned a date of 1393-1443 cal AD (Beta-359081; 2-sigma intercept 89.2%).

Figure 14. Correlation between the three uppermost spikes in MS readings (left) with cultural deposits from column sample (right).
LOI testing on samples within this zone indicates that the percentage of organic material increases with depth (4 to 17%). The percentage of water content also increases with depth (1 to 46%). The percentage of calcium carbonates decreases with depth (40 to 28%). The shell midden deposits and cultural occupancy in Zone 1 likely contribute to the percentages of organics, water, and carbonates. The increase in the percentage of water in the samples is likely associated with water being bonded to the organic material. Organic material, such as vegetation, could have decreased due to human habitation and activities that hindered plant growth at the site. The calcium carbonate decrease may correlate to the amount of shellfish that was gathered over the course of CCO-297’s habitation, and may be representative of an increased amount of shell accumulation that was present during the later periods of occupation.

MS testing shows an overall declining trend of magnetic signatures from the soils in this zone, but contains four peaks in MS readings that range from the high-20s to the mid-30s. MS testing on the column and core samples revealed four spikes in magnetic readings, which occur where burned layers and charcoal lenses are present. The lowest of the four spikes may be from the same reading as the third spike. This is due to the core samples being extracted approximately 1 m east of the column sample. This would have caused the charcoal lens (CL #3) to be present in the lower depths of the column sample and in the upper depths of the core sample. The increased magnetic readings indicate the effects of heat alteration (Goldberg and Macphail 2006:350; Jones 2007:22) (Figure 14).
Radiocarbon testing taken on three of the charcoal lenses indicated the lowermost charcoal lens (field designated CL#5) yielded a date from 1505-1680 cal AD (D-AMS 005232; 2-sigma intercept 100%), with a mean date of 1592 cal AD. The charcoal lens positioned above (CL#4) is separated by approximately 30 cm of burned shellmidden (Feature 43), and dates to 1619-1882 cal AD (D-AMS 005230; 2-sigma intercept 100%), with a mean date of 1750 cal AD. CL#3 dates from 1708-1910 cal AD (D-AMS 005229; 2-sigma intercept 89.8%), has a mean date of 1809 cal AD, and is separated by approximately 25-30 cm of burned layer (Feature 42). Assuming these burned layers are single events, this calculates to a 158-year difference between the mean dates and formation of CL#5 and CL#4, and a 59-year difference between CL#4 and CL#3. A description of the radiocarbon dates used in this study is discussed in Chapter 5.

Phosphate testing indicates that the highest amount of phosphorus present (a value of 5) is situated at 225-275 cmbd1, and then decreases into Zone 2. Macrofossil material from Zone 1 is dominated by charcoal fragments and Atriplex sp., but also contains Scirpus sp., Cyperus sp., Distichlis spicata, and unknown seeds. Atriplex are the most prevalent species of seeds identified in Zone 1, and they comprise the highest number of seeds counted (47) in a single sample (240-245 cmbd1 depth). The percent of unknown (unidentifiable) seeds are higher in Zone 1 than in any other, and dominate the mid to lower elevations of the deposit. It is possible that the overall distribution of seeds in Zone 1 correlates to prehistoric cultural activities. The absence of seeds from the upper to mid elevation of the zone might be attributed to impeding and/or depleting plant
populations at the site by overexploitation, or other forms of human activities that took place during the duration of cultural habitation.

Foraminifera species *Trochammina inflata* are present in the 280-285 cmbd1 level; however, testing for the presence of these fossils was not conducted in other samples from Zone 1. Quantities of charcoal fragments in Zone 1 are extremely high, with a rough estimation of over 1,000 fragments present in each sample, with the exception of samples at the 211-217, and 280-285 cmbd1 depths. Samples taken at the 211-217 cmbd1 depths contained approximately 200 fragments. To confirm the decline in charcoal numbers this result was duplicated twice by analyzing a different sample from the same depth. The results from the method used to quantify charcoal fragments discussed in the previous chapter do not illustrate the higher amounts of charcoal observed in the charcoal lens layers. However, samples containing charcoal lenses observed with the naked eye had a black color, greasy texture, and contained higher amounts of charcoal fragments when compared to other column and core samples. The decline in charcoal numbers at the 280-285 depth correlates to a transition from cultural deposits to natural deposits.

Diatom analysis at the 280-285 cmbd1 depth recorded 23 species of diatoms, mostly from fresh water origin, but also included diatoms derived from brackish and marine habitats. The most prevalent is *Neofragilaria* sp., and is associated with freshwater conditions (Appendix F). The pH values in this zone are fairly neutral, ranging from 7.20 to 7.41. The lower portion of this zone displays an abrupt boundary (<2.5 cm) as it transitions into Zone 2.
Zone 2: Tidal Marsh Deposits

Zone 2 (285-340 cmbd1) is characterized by a high percentage of autochthonous organics within the stratum and a complete absence of cultural deposits. This stratum, Stratum V (5Ag), is a bay tidal deposit that formed in a wetland environment. A radiocarbon sample taken at the 300-305 cmbd1 depth returned a mean date of 1203 cal AD (DAMS-005228; 2-sigma intercept 98.8%). LOI testing indicates the highest concentration of organic material is present in this zone – peaking at 33% at the 290-295 cmbd1 depth, and declining to 6.5% at 330-340 cmbd1. Calcium carbonate readings drop from 11% in the uppermost segment, to 2% within the lower extent of the zone. Water percentage in this zone is higher than any other and drops drastically from 47% to 14% within the 325-340 cmbd1 depths.

MS readings increase slightly with depth from 2.3 to 8.9 SI units, while phosphate values are erratic, peaking, and declining in various ranges from 4.5 to 2.5. Macrofossil analysis indicates a sharp drop in the amount of *Atriplex* and *Scirpus*, as well as charcoal, compared to Zone 1. Most seeds present appear to be *Distichlis spicata*, while amounts of *Cyperus* are also recorded. *Trochammina inflata* fossils are found throughout Zone 2.

Microfossil analysis indicated at least 26 species of diatoms in Zone 2. Most of the specimens identified are of freshwater origin including *Neofragilaria* sp. The samples also contained species found in brackish-marine environments such as *Navicula peregrine* and *Diploneis smithii*, but in far fewer numbers. The pH values in this zone are fairly neutral, ranging from 7.48 to 7.25. The lower portion of this zone displays an abrupt boundary (<2.5 cm) as it transitions into Zone 3 at the depth of 340 cmbd 1.
Zone 3: Pre-Bay Paleosol Deposits

Zone 3 (340-470 cmbd1) contains two components (3a and 3b). Zone 3a (340-350 cmbd 1) is associated with Stratum V (5Ag) (Kaijankoski and Myer 2015). This section of deposits is characterized by the presence of five freshwater species of diatoms (Neofragilaria sp., Aulacoseira sp., Planothidium lanceolatum, Tabularia fasiculata, and Gomphonema sp.). Only one species, Cyclotella striata, is associated with fresh and brackish water. No foraminifera species are present in this zone. The organic percentage in the sediments range from 5 to 6.5%. One Atriplex sp. seed was recorded out of nine, with eight being unidentifiable fragments. The sediment is silty, and mostly contains subangular to angular fine sands composed of quartz. A radiocarbon sample retrieved from the SLT 48 trench at a depth of 340-350 cmbd2 returned a mean date of 4910 cal BC (BETA-359082; 2-sigma intercept 98.7%).

When comparing the depths of where radiocarbon samples were taken between the SLT 48 and DI 25 trenches, there is ~40 cm of sediment separating the sample dates of 1203 cal AD (D-AMS 005228) and 4910 cal BC (BETA-359082). This apparently slow rate of sedimentation can be explained in a number of ways. It is possible that there is some kind of hiatus or disruption that impaired sedimentation, such as material being washed away or removed, or possibly older material has been incorporated into the site. It is also possible that there is a different stratigraphic depth to Stratum V occurring in the SLT trench compared to the DI 25 trench as “both the thickness and elevation of this stratum varies considerably across the site” (Kaijankoski and Meyer 2015:367). A different elevation of Stratum V between the two trenches might have the result of
producing more recent dates in shallower sample depths in the DI 25 trench, while the SLT trench would produce older radiocarbon dates from the same sample elevation.

Zone 3b (350-470 cmbd1) is associated with Stratum V (5Cg), a gleyed parent material (Kajjankoski and Myer 2015). It is characterized by a decrease in the percentage of organics (5 to 1.7%), calcium carbonates (7 to 2%), and a lack of microfossil and macrofossil material. Zone 3b contains two seed fragments that could not be identified. No foraminifera or diatom species were observed, and three phytoliths were recorded. Sands and silts observed under the microscope appear coarse, with very fine sand particles composed almost entirely of subangular to angular quartz. Phosphate values ranged from 3.5 to 2, while pH remained fairly neutral in the entirety of Zone 3, with readings of 7.25 to 7.62. MS readings show a gradual increase (8.9 to 15.8) with depth in Zone 3. No stratigraphic boundary or diffusion was encountered when auguring in the DI 25 trench that was terminated at the 470 cmbd1 depth. A radiocarbon sample taken at the lower depths of this stratum (480 cmbd2) was extracted from the SLT trench and returned a date of 10,118 to 9797 cal BC (BETA-359083; 2-sigma intercept 98.6%).

**Tidal Marsh Development**

The analysis of column and core samples within and below CCO-297 demonstrates the development of a slightly brackish tidal marsh paleoenvironment within the San Francisco Bay estuary, and its correlation with the formation of prehistoric site CCO-297. LOI testing indicates that the formation of slightly brackish waters that contributed to the marshes evolution (Zone 2) begins at 335 to 340 cmbd1. Both organic
and calcium carbonate percentages rapidly increase in core elevation beginning at the
335-340 cmbd1 depth. Organic content in the core samples peak at 33% at 290-295
cmbd1 depth before they begin to decline.

The depth at which the vegetation formation of the high marsh (above MHW) was
at its peak (290-295 cmbd1 depth) occurs before cultural occupation of the site began at
1350 cal AD. This peak of middle to high marsh vegetation formation also occurs after
1203 cal AD, as indicated by the radiocarbon date (DAMS-005228; 2-sigma intercept
98.8%) retrieved from the 300-305 cmbd1 depth. This places the peak of the marsh’s
vegetation around 700 cal BP, a period that is associated with maturation of marshes to
high marsh levels in other sediment samples in the Bay Area, and the development of
tidal conditions similar to the present day (Goman et al. 2008:1133). The peak of high
marsh development also appears during the MCA, a period from about 800 to 1350 AD
(Stine 1994; Jones and Klar 2007) and is associated with mega-droughts, dry conditions,
and periodic floods in the San Francisco Bay (Malamud-Roam et al. 2006:1591; Goman
et al. 2008:1135).

The increase in the percentage of water in the samples is likely associated with
water being bonded to the organic material. The calcium carbonate increase may be due
to a rise in biotic species as the marsh evolved, such as mollusk populations. Organic
percentage is an important indicator of salt or brackish marsh development because it can
track vegetation growth, which is an essential factor in marsh evolution. The decline of
magnetic signatures at this depth is indicative of a decline in mineralogic material
reaching the site. The decline in mineralogic material suggests that marsh accretion was
occurring as evident in the percentage of organics present (Goman et al. 2008: 1133). The plant accumulation would be able to keep pace with relative sea level rise, and would have impeded mineralogic material in clay and silt sediments from depositing in the high marsh zone during tidal processes.

A salt marsh is formed when a tidal flat builds up. This occurs when clay-sized and fine silt-sized particles are transported to the coast by rivers, form larger aggregates when meeting salt water, settle out as mud, and are deposited by tides. This area then develops into a salt marsh once it has been colonized by salt tolerant plants (Huggett 2011:373-374). If a significant influx of freshwater is present, the saltwater marsh will lose salinity and become brackish. The study of seed macrofossils can reconstruct the marsh paleoenvironment and help reveal where marsh zones and terrestrial landforms were once positioned.

Macrofossil analysis revealed that seeds of *Distichlis spicata* are predominately encountered along the full length of the Zone 2 core segment (Figure 15). This plant is noted as “an important species in coastal salt marshes, brackish marshes, and tidal wetlands” and “is the dominant or codominant species in the transition zone of the midmarsh” (Lonard et al. 2013:105,108). Traut (2005) notes that the typical dominant plant species found in mid-zonation of salt marshes within northern California are *Distichlis spicata*, along with *Salicornia virginica* (pickleweed). *D. spicata* has also been observed in the San Francisco Bay estuary environments dominating the high marsh, located slightly higher than *S. virginica* (Goman et al. 2008:1127).
Microfossil analysis revealed the diatoms present in the core deposits are primarily of freshwater origin, but the samples also contain species associated with brackish and marine environments (Appendix F). The trend of freshwater species becoming intermixed with brackish water types is more prevalent in the higher elevations of the core sample. This indicates that a freshwater environment began depositing the diatoms in-between the depths of 350 to 385 cmbd1 within Zone 3b. While freshwater diatoms are the most prevalent, others of brackish and marine origin are observed in higher and younger sample elevations (280-285, 305-310, and 325-330 cmbd1). The deepest sample (385-390 cmbd1) did not record any diatom species, and only three phytoliths. This assemblage of diatoms infers that the site is in a tidal marsh in slightly

Figure 15. *Distichlis cf. spicata* seeds from macrofossil testing of Zone 2.
brackish water with the possibility that “in wet conditions the waters at the site are relatively fresh and in the drier months the waters are more saline” (Strarratt personal communication 2014) (Appendix F).

Further evidence of a tidally influenced slightly brackish marsh along the entirety of Zone 2 comes from the recorded presence of foraminifera – a one-celled marine organism that creates a shell, called a test. The tests of foraminifera found in macrofossil analysis were identified as *Trochammina inflata*. *T. inflata* is considered a “high marsh normal salinity species” (Fatela et al. 2014:125). The species inhabit the high marsh zone occurring above MHW in brackish to near saline conditions in many parts of the world, and dominate the North American and South American mid latitude (40-50°) region (Hayward and Hollis 1994:196). Foraminifera, commonly found in the intertidal zone (Wesleyan University 2001), have also been recorded in surface and subsurface samples from high, middle, and low marsh zones in saline to brackish conditions (Goldstein and Harben 1993; Hayward and Hollis 1994). One explanation for variation in habitation of marsh zones is related to precipitation and salinity. *T. inflata* studies in Portugal had observed foraminifera inhabiting the lower zones of brackish marshes when salinity is lowered due to high precipitation periods (Fatela et al. 2014:125). Their research showed that an increase in the influx of freshwater caused low salinity foraminifera species (*H. manilansis, H. wilberti, T. irregularis, and P. limnetis*) to inhabit the high marsh.
**Archaeological Site Formation**

A sample of organic-rich carbonaceous marsh sediments recovered from unit N0/E5 at 300 cmbd1 returned a calibrated age estimate of ca. 800-700 cal BP (DAMS-005228; 2-sigma intercept 98.8%). The formation of site CCO-297 appears to have occurred with the transformation of natural marsh deposits to cultural deposits at 280-285 cmbd1. This site is noted as being “one of the best-dated single-component sites on the San Francisco Bay Shore” and was occupied from approximately 600 to 180 cal BP (DeGeorgey 2015). These dates would temporally place the site in a period known as the “Little Ice Age” (550-200 cal BP) that brought “unusually cool and wet conditions”, lowered salinity in the San Francisco Bay (Malamud-Roam et al. 2006: 1570), and would have kept lowland rivers and lakes full (Jones and Klar 2007:302).

Evidence from CCO-297 indicates the indigenous populations that inhabited the site conducted seasonal clamming (DeGeorgey 2013; Eerkens et al. 2014). The rapid increase of calcium carbonate signatures in LOI testing is undoubtedly related to the marine shells within the anthropogenic deposits. The decreasing trend of organic percentages most likely indicates that the landscape had changed from natural marsh, to cultural deposits. Seed species of *Atriplex* and *Scirpus* (now in the genus *Schoenoplectus*) extracted from the lower portions of the cultural zone are indicative of a terrestrial setting situated within the high tide line or near the edges of the marsh.

It is possible that the prehistoric inhabitants at CCO-297 gathered these plants for a variety of uses. Various species of *Scirpus* (tules or bulrushes) have been used by some Native Californian groups for constructing houses, reed boats, clothing, footwear, duck
decoys, and basketry, and also as a food sweetener (Anderson 2006:205). Other uses include the making of napkins, mats, archery targets, fishing nets, flour, and used to treat poison-oak rashes (Lightfoot and Parrish 2009:221, 263, 287). *Atriplex* (saltbush) seeds have been used by some Native Californians for a pinole, and the roots of the plant were used for soap (Beard 1977:54). *Atriplex* has also been used as a liniment to treat bone and muscle pain (Owen 1962:109). *Distichlis spicata* (saltgrass), found primarily in Zone 2, was also used by some of the prehistoric inhabitants of California, “salt came from the globules adhering to saltgrass (*Distichlis spicata*), mineral deposits, or kelp, or was scraped from the beach” (Anderson 2006:242-243).

The laminated stratum (5Ag) containing a mix of organics and shell located in the lower depths of the cultural zone (~260-270 cmbd1) corresponds with a decrease in percent of calcium carbonate, as well as a sharp fluctuation in the percent of organic material. This laminated section may have been formed by a major wet event, such as terrestrial or bay flooding. Similar flood deposits and unconformities observed in core samples around the San Francisco Bay have been dated from 850-450 cal BP (Malamud-Roam et al. 2006:1591; Goman et al. 2008:1135) including a flood event dated to 530 cal BP (Goman and Wells 2000:216). These wet periods have been attributed to strong El Niño events that are associated with extreme precipitation in northern California, while inactive periods are characterized with droughts (Goman et al. 2008:1135). These events could have affected the growth and spread of marsh vegetation, as well as impacting the ecosystem of shellfish habitats, and in turn, the amount available for gathering this resource.
The timing of the formation of the slightly brackish marsh and Native American occupation of the CCO-297 is not a coincidence, and is directly related to human adjustments to environmental conditions. The sites initial occupation dates to 1350 cal AD (DeGeorgey 2015), a time of a major climatic transition from dry and drought conditions during the MCA that end in 1350 cal AD (Jones and Klar 2007:304), to wetter and cooler conditions of the LIA that began in 1450 cal AD (Malamud-Roam et al. 2006:1593). Professional discourse on the effects that the MCA had on California peoples is still ongoing, and includes question concerning major settlement shifts, migrations, and/or breakdowns in exchange and population declines (Schwitalla 2013). Most characterizations of the MCA suggest droughts were “severe enough to cause problems for residents of poorly watered areas of native California” (Jones and Klar 2007:302). Data shows a significant increase in the number of sites being occupied beginning around 1250 cal AD along the San Francisco Bay Area and the Central Coast (Jones and Klar 2007:304-305). The peak of marsh development around 1203 cal AD would have provided the first inhabitants of CCO-297 with ecosystems that were likely more diverse than in previous times.

The purpose of this chapter was to present the results of the data analyses and interpret the findings. The following chapter concludes the thesis by summarizing the findings and then explaining the studies significance. Lastly, recommendations for future research are given.
Chapter 8. Conclusions

Summary

In this thesis, I have analyzed stratigraphic data produced from column and core samples taken from CCO-297 and revealed that the development and evolution of a paleo-marsh contributed to the site’s formation. Analyzed data from LOI, macrofossil, microfossil, and MS testing detected the formation of a slightly brackish marsh existed at CCO-297 before cultural occupation began at 1350 cal AD. LOI data shows that the percentage of organics drastically increases in Zone 2 and corresponds with the growth of vegetation and its dynamic zonation of specific species. This is also apparent in the increase of carbonate calcium that gradually accumulates in Zone 2. Progradation and accretion of the marsh likely occurred from the accumulation of sediments over time, as evident in MS testing. Seeds recovered in macrofossil samples, including *Atriplex* sp. and *Distichlis spicata*, are indicative of salt tolerant plant species that occupy either the high and/or middle salt or brackish marsh ecotones. Species of *Scirpus* inhabit the brackish marsh zones from mid to low levels, while *Cyperus* sp. are commonly found in wetland environments. MS testing shows a decrease in magnetic readings in Zone 2, this is likely attributed to a decline in mineralogical material reaching the site and corresponds to vegetation growth associated with the marsh that kept pace with relative sea level rise.

The presence of foraminifera species *T. inflata* during macrofossil testing indicates that a tidally influenced brackish water was present throughout Zone 2. Diatoms identified in microfossil analysis, including *Neofragilaria* sp., show that species
in this zone are primarily fresh water in origin, but range from brackish to marine in environmental habitats. The diatoms analyzed from Zone 3a and Zone 2 indicate that this zonal interface is likely a transition point from a strictly freshwater deposit to a slightly brackish deposit. This is evident in the absence of foraminifera in Zone 3a, indicating that the waters at this time were not saline, and that tides from the San Francisco Bay had not yet influenced the fresh waters.

There are several explanations as to why the San Francisco Bay tides appear to reach the site sometime shortly before 1200 years ago, and not earlier. It is possible that a freshwater flow impeded tidally influenced waters from reaching the site. Kaijankoski and Meyer’s (2015:375) investigation at CCO-297 concluded that portions of a wetland transitioned to a terrestrial environment around 2000 years ago, and was likely due to loss of freshwater input and/or infilling with sediments. They also determined that based on a sea-level curve for the Bay Area, and other lines of evidence, rising sea levels reached CCO-297 sometime after 1000 cal BP (2015:375). Findings from LOI, MS, macrofossil, and microfossil data from this thesis suggest saline waters and tidally influenced brackish marsh evolution began in Zone 2, about 40 cm below the 1203 cal AD date (D-AMS 005228; 2-sigma intercept 98.8%) taken at the 300-305 cmbd1 depth.

Site formation of CCO-297 occurred slightly after the vegetation evolution of the tidally influenced brackish marsh was at its peak (~1203 cal AD) as indicated by the percent of organic material in the sediment and shifts in magnetic signatures. The accumulation of sediments likely caused marsh progradation and the formation of the terrestrial landform. CCO-297 was situated on the edges of a tidally influenced slightly
brackish marsh during its initial occupancy. A laminated stratum in the lower depths of the cultural zone dating between 1393 to 1443 cal AD (BETA-359081; 2-sigma intercept 89.2%) can be attributed to high precipitation occurrences, such as El Niño events, as seen in other core samples from this period in the San Francisco Bay (Goman and Wells 2000; Malamud-Roam et al. 2006; Goman et al. 2008).

The formation of a slightly brackish marsh during the terminal phase of the MCA created a new ecosystem on the landform that was not present in previous times. The end of dry and drought conditions at approximately 1350 cal AD likely provided fresh water to nearby streams and ponds. CCO-297’s proximity to different environments, including freshwater streams and wetlands, salt marshes, brackish marshes, and the bay, would have provided an array of different resources available for subsistence. The occupation of CCO-297 at 1350 cal AD correlates to the near beginning of cooler and wetter conditions brought on by the LIA in 1450 cal AD. High precipitation occurrences caused terrestrial or bay flooding in the early occupancy of site CCO-297. The initial occupation of CCO-297 fits a time pattern when sedentary habitation of prehistoric sites began along the San Francisco Bay and Central Coast, and ends around the time of Spanish contact.

**Conclusions**

This study of diachronic landscape reconstruction reveals the timing of fresh water to brackish marsh evolution along the San Francisco Bay estuary. The results of this thesis place CCO-297 within the context of an evolving paleo-landform, one that was affected by shifting climatic environments from the MCA to the LIA. This is important
because understanding and interpreting culture and cultural change is not possible without an appreciation of the environmental context (Rapp and Hill 2006:274). This study provides an understanding of the natural and cultural deposits that contributed to prehistoric shellmound formation along the San Francisco Bay estuary, and furthers the knowledge of how environmental factors affected site-formation processes during the cultural Late Period. The methods and findings of this research can be applied to future archaeological investigations that seek to analyze prehistoric shellmound formation processes and reconstruct estuarine palaeoenvironments, especially during the climatic transition periods between the MCA and LIA.

**Future Research**

Future research on shellmound site formation should address depositional phases of the anthropogenic soils that comprise the mound. There is much professional debate as to how and why large shellmounds were constructed (Lightfoot 2004: 17; Luby et al. 2006: 192). Questions include if construction was by “haphazard dumping episodes over hundreds of years or the product of intentional, planned construction?” (Luby et al. 2006:197).

Evidence at CCO-297 suggests that sections of CCO-297’s mound located in the DI 25 trench could have been constructed in a series of major building episodes, which took place in pulses that formed the deposits. During this thesis research, magnetic susceptibility testing on column and core samples from the cultural deposits (Zone 1) revealed distinct spikes in magnetic readings were burned layers and charcoal lenses
where visibly present. The increased magnetic readings are likely indicating the effects of heat alteration (Goldberg and Macphail 2006:350; Jones 2007:22). Possible explanations for a periodic, rather than long-term, building of this mound segment might be due to cooking activities such as massive clambakes, where the charcoal lenses represent the fuel source. Similar periodic, rather than long-term, clambake events have been associated with prehistoric shellmound construction in Southwest Mexico (Voorhies 2004: 51). These major pulsating events might be associated with mortuary observances, feasts, and ceremonies as seen with prehistoric mound builders from the lower Mississippi Valley (Schweikhardt et al. 2011: 2310). The charcoal lenses could also be the remnants of bonfires created near the shore for fishing at night. The bonfire would have acted as a fishing lure and was a method used by some northwestern tribes of California (Kroeber and Barrett 1960:86-87).

Magnetic susceptibility testing on shellmound deposits can reveal depositional events that are not visible with the naked eye. A possible reason why evidence for stratigraphic layering in shellmound studies can be misinterpreted is due to the appearance that the deposits are a single homogeneous event. These deposits are typically attributed with a few radiocarbon dates (one from the surface and one from the base) which often produce ages that are statistically the same, and are interpreted as single deposit events (Rosendahl et al. 2014:21). A magnetic susceptibility test on deposits could indicate a strong relationship between cultural depositional processes and magnetic properties, and reveal cultural layers (e.g., burned and/or heat altered layers) that are not visible to the naked eye during field investigations. This method could aid in
archaeological site formation investigations concerning periodic or long-term shellmound construction.
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Hinde, H.P.

Hughes, M.K., and L.J. Graumlich

Huggett, Richard J.

Hylkema, Mark G.

Ingram, B.L.

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Kroeber A.L., and S.A. Barrett  

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Levy, R.S.  

Lightfoot, Kent  

Lightfoot, Kent G. and E. M. Luby  

Lightfoot, Kent G. and Otis Parrish  

Lonard, Robert L., Frank W. Judd, and Richard Stalter  

Loud, Llewellyn L.  

Luby, Edward M.  

Luby, Edward M., Clayton D. Drescher, and Kent G. Lightfoot  
Martin, A.C., and W.D. Barkley

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Milliken, Randall, Laurence H. Shoup, and Beverly R. Ortiz

Moratto, Michael J.

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Nelson, Nels, C.

Nichols, F.H, J. E. Cloern, S. N. Luoma, and D. H. Peterson

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Owen, R.C.

Pollard, Mark A.


Ramsey, Eleanor

Rapp, George (Rip), and Christopher L. Hill

Reineck, H. E., and I.B. Singh

Renfrew, C.

Robinson S.W.

Rogers, Robert
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Rosenthal, J.S., and J. Meyer

Schiffer, Michael


Schoenherr, A.A.

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Voorhies, Barbra

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University of Nevada, Reno
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Appendix A. Raw Data from LOI Test
## Appendix B. Raw Data from Magnetic Susceptibility Test

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Note: The table represents the number of occurrences in each time interval.
Appendix D. Raw Data from Phosphate Test

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## Appendix E. Raw Data from pH Test

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Appendix F. Diatom Analysis
Dear Robert and Michelle,

Five sediment samples from core SB-02 were analyzed for siliceous microfossils. Smear slides were made using Naphrax ($r = 1.71$).

Ten transects were scanned on each slide. All slides contained poorly to moderately well preserved microfossils. Most diatoms show evidence of physical breakage. This preservation is consistent with the preservation in marsh deposits around San Francisco Bay (SFB). The number of specimens enumerated is insufficient for a statistical interpretation but does give you some idea of the environment of deposition.

The sediments in the lowest samples is coarser than the upper three samples. The environments are representative of the SFB environments in which these taxa are found. The diatoms of SFB were described in some detail in Laws (1988). Although the assemblages are mixed the predominance of freshwater taxa suggests that the site is in a tidal marsh in slightly brackish water. It is also possible that in wet conditions the waters at the site are relatively fresh and in the drier months the waters are more saline.

F = freshwater
FB = fresh and brackish water
B = brackish water
BM = brackish water and marine
M = marine
C = cosmopolitan

For my records, would you please give me the sample locality and any other information available on these samples.

Here is a list of the taxa identified in the samples and their relative abundances.

280-285 cm

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<thead>
<tr>
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<td>Anomoecies sp.</td>
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<td>Cocconeis placentula</td>
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<td>Cocconeis sp.</td>
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<td>M</td>
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<tr>
<td>Commonnesiopsis sp.</td>
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<td>C</td>
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<tr>
<td>Gomphonema sp.</td>
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<tr>
<td>Marine fragments</td>
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<tr>
<td>Charcoal</td>
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305-310 cm

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<tr>
<td>Denticula sp.</td>
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<tr>
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<td>F</td>
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Hope this information helps. Please let me know more about your project.

Sincerely,

Scott W. Starratt
Research Geologist
Appendix G. Radiocarbon Analysis
Dear Alex,

Your samples submitted for radiocarbon dating have been processed and measured by AMS. Following results were obtained:

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<td>D-AMS 005224</td>
<td>Peat/soil 2189</td>
<td>25.0</td>
<td>88.63</td>
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<td>1153</td>
<td>29</td>
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<td>D-AMS 005225</td>
<td>Shell 2227</td>
<td>-6.4</td>
<td>87.87</td>
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<td>29</td>
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<tr>
<td>D-AMS 005226</td>
<td>Soil 2255</td>
<td>-35.2</td>
<td>94.99</td>
<td>0.36</td>
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<tr>
<td>D-AMS 005227</td>
<td>Wood 2013</td>
<td>27.1</td>
<td>94.82</td>
<td>0.32</td>
<td>427</td>
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<tr>
<td>D-AMS 005228</td>
<td>Peat/soil 2804</td>
<td>-22.2</td>
<td>88.92</td>
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<tr>
<td>D-AMS 005229</td>
<td>Shell 2285</td>
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<td>870</td>
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<tr>
<td>D-AMS 005230</td>
<td>Shell 2887</td>
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<td>88.77</td>
<td>0.33</td>
<td>957</td>
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<tr>
<td>D-AMS 005231</td>
<td>Soil 2889</td>
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<td>D-AMS 005232</td>
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<td>87.54</td>
<td>0.28</td>
<td>1060</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

All results have been corrected for isotopic fractionation with δ¹³C values measured on the prepared graphite using the AMS spectrometer. These δ¹³C values provide the most accurate radiocarbon ages but cannot be used to investigate environmental conditions.

Best regards,

Ugo Zoppi

550 17th Avenue, Suite 550, Seattle WA 98112
Tel (206) 231-8557 – Fax (206) 231-5916 – www.directAMS.net
September 27, 2013

Mr. Alex DeGeorgey
AlnAC
13 Third Street
Santa Rosa, CA 95401
USA

RE: Radiocarbon Dating Results For Samples S48-285cm, S48-340-350cm, S48-460cm

Dear Mr. DeGeorgey:

Enclosed are the radiocarbon dating results for these samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

The web directory containing the table of results and PDF download also contains pictures including, most importantly, the portion actually analyzed. These can be saved by opening them and right clicking. Also a csv spreadsheet download option is available and a quality assurance report is posted for each set of results. This report contains expected versus measured values for 3-5 working standards analyzed simultaneously with your samples.

All results reported are accredited to ISO-17025 standards and all analyses were performed entirely here in our laboratories. Since Beta is not a teaching laboratory, only graduates trained in accordance with the strict protocols of the ISO-17025 program participated in the analyses. When interpreting the results, please consider any communications you may have had with us regarding the samples.

If you have specific questions about the analyses, please contact us. Your inquiries are always welcome.

Thank you for preparing the analyses. As always, if you have any questions or would like to discuss the results, don’t hesitate to contact me.

Sincerely,

[Signature]
REPORT OF RADIOCARBON DATING ANALYSES

Mr. Alex DeGeorgey
AltaAC

Report Date: 9/27/2013
Material Received: 9/12/2013

<table>
<thead>
<tr>
<th>Sample Data</th>
<th>Measured Radiocarbon Age</th>
<th>13C/12C Ratio</th>
<th>Conventional Radiocarbon Age(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta-359081</td>
<td>5400 ± 30 BP</td>
<td>-66.0 0/00</td>
<td>320 ± 30 BP</td>
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<tr>
<td>ANALYSIS</td>
<td>AMS-Standard delivery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATERIAL/PRETREATMENT</td>
<td>(wood) acid/alkali/acid</td>
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<td></td>
</tr>
<tr>
<td>2 SIGMA CALIBRATION :</td>
<td>Cal AD 1350 to 1340 (Cal BP 520 to 810) AND Cal AD 1400 to 1440 (Cal BP 550 to 510)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Beta-359083 | 8030 ± 30 BP              | -27.3 0/00    | 6010 ± 30 BP                     |
| ANALYSIS   | AMS-Standard delivery    |               |                                  |
| MATERIAL/PRETREATMENT | (organic sediment) acid washes |               |                                  |
| 2 SIGMA CALIBRATION : | Cal BC 4850 to 4930 (Cal BP 6840 to 6780) AND Cal BC 4810 to 4830 (Cal BP 6780 to 6760) |               |                                  |

| Beta-359083 | 10140 ± 40 BP              | -27.8 0/00    | 10190 ± 40 BP                     |
| ANALYSIS   | AMS-Standard delivery    |               |                                  |
| MATERIAL/PRETREATMENT | (organic sediment) acid washes |               |                                  |
| 2 SIGMA CALIBRATION : | Cal BC 10400 to 9900 (Cal BP 12050 to 11750) |               |                                  |

Data are reported as RCYBP (radiocarbon years before present), (present = AD 1950). By international convention, the modern reference standard used is the 14C activity of the NBS (National Bureau of Standards) of the International Atomic Energy Agency (IAEA) and is based on the Libby half-life (5568 years). Quoted errors represent 1 relative standard deviation statistic (68% probability) and are based on combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (δ13C) are corrected relative to the PDB-1 standards.

The Conventional Radiocarbon Age represents the measured Radiocarbon Age corrected for isotopic fractionation, calculated using the δ13C. On rare occasions where the Conventional Radiocarbon Age was calculated using an assumed δ13C, the uncertainty and the Conventional Radiocarbon Age will be followed by **. The Conventional Radiocarbon Age is not calendar calibrated. When available, a calendar calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result." for each sample.
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variates: C13/C12=-26; lab: multi=1)

Laboratory number: Beta-359091

Conventional radiocarbon age: 520±30 BP

2 Sigma calibrated results: Cal AD 1330 to 1340 (Cal BP 620 to 610) and
(95% probability) Cal AD 1400 to 1440 (Cal BP 550 to 510)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 1420 (Cal BP 530)

1 Sigma calibrated result: Cal AD 1410 to 1430 (Cal BP 540 to 520)

(68% probability)

References:
Database used: INTCAL98

References to INTCAL98 database

Mathematical used for calibration scenario
A simplified approach to Calibrating C14 Data:

Beta Analytic Radiocarbon Dating Laboratory
1885 S.W. 7th Court, Miami, Florida 33135 • Tel: (305) 667-3187 • Fax: (305) 667-6944 • E-Mail: hum@radiocarbon.com

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Laboratory number: Beta-359052)

Conventional radiocarbon age: 6010±30 BP

2 Sigma calibrated results:
- Cal BC 4990 to 4830 (Cal BP 6940 to 6780) and
- Cal BC 4810 to 4810 (Cal BP 6760 to 6760)

Intercept data

Intercepts of radiocarbon age
with calibration curve:
- Cal BC 4910 (Cal BP 6860) and
- Cal BC 4860 (Cal BP 6810) and
- Cal BC 4860 (Cal BP 6810)

1 Sigma calibrated result:
- Cal BC 4840 to 4840 (Cal BP 6890 to 6880)

References:
- Database used
  INTCAL09

References to INTCAL09 database

Mathematical model used for calibration scenario
- A Simplified Approach to Calibrating C14 Doses

---

Beta Analytic Radiocarbon Dating Laboratory
4933 S.W. 7th Court, Miami, Florida 33135 • Tel: (305) 607-3167 • Fax: (305) 607-3964 • E-Mail: beta@radiocarbon.com

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

Laboratory number: Beta-359083

Conventional radiocarbon age: 10190±40 BP

2 Sigma calibrated result: Cal BC 10160 to 9800 (Cal BP 12050 to 11750) (95% probability)

Intercept data

Intercepts of radiocarbon age with calibration curve:
- Cal BC 10020 (Cal BP 11970) and Cal BC 9920 (Cal BP 11870) and
- Cal BC 9880 (Cal BP 11840)

1 Sigma calibrated result: Cal BC 10040 to 9860 (Cal BP 11990 to 11820) (68% probability)

References:
- Database used: INTCAL09
- References in INTCAL09 database:
- Mathematics used for calibration scenario:
  - A Simplified Approach to Calibrating C14 Data:

Beta Analytic Radiocarbon Dating Laboratory
4915 S.W. 74th Court, Miami, Florida 33155 • Tel: (305) 667-7167 • Fax: (305) 663-9964 • E-Mail: betajl@radiocarbon.com