SUBSISTENCE PATTERNS AS MARKERS OF CULTURAL EXCHANGE: EUROPEAN AND TAÍNO INTERACTIONS IN THE DOMINICAN REPUBLIC

James M. VanderVeen

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Doctor of Philosophy
in the Department of Anthropology,
Indiana University

September 2006

Accepted by the Graduate Faculty at Indiana University,
in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

_____

Geoffrey W. Conrad, Ph.D.
Chairperson

_____

Simon C. Brassell, Ph.D.

Doctoral Committee

_____

K. Anne Pyburn, Ph.D.

_____

Richard R. Wilk, Ph.D.

Date of Oral Examination: 24 August 2006

© 2006
James M. VanderVeen
ALL RIGHTS RESERVED

ACKNOWLEDGEMENTS

> Columbus scholarship is a fertile ground for that peculiar academic blindness whereby an interesting but indefensible hypothesis is followed to its logically necessary but increasingly lunatic conclusion.
>
> – Peter Hulme

My descent into the lunacy that surrounds all research regarding Columbus, as well as the people he met, was abetted by many individuals and groups that deserve mention here. Archaeology is rarely a task that is done by a single individual, and typically includes multidisciplinary aspects. This project is no exception. Much of the data collection in the field was done collaboratively by the outstanding team of researchers who were part of the Bahía Isabela Archaeology Project at one time or another. In particular, Emma Bate was a valuable resource in terms of her excavation skills, her ideas about the people whom we were studying, and her camaraderie. Rafael Cueto and Carlos Passalaigue lent their expertise both in the field and to issues regarding the local culture. Charles Beeker, John Foster, and their underwater archaeologists provided tremendous support to the endeavors of the research team, and they were all willing to get dirty when they were not able to get wet.

The project would not have been possible without the generous assistance of the government and people of the Dominican Republic. The officials and staff at the Museo del Hombre Dominican facilitated my research in their country, quickly resolved any

issues that I faced, and offered freely of their time and resources. The current director, Carlos Hernández Soto, his predecessor, Carlos Andújar Persinal, and the rest of the museum personnel, especially Juan Rodríguez, made my time in the Dominican productive and enjoyable. The staff at the museum on the grounds of La Isabela also lent support in whatever ways they could. Adding their hospitality, valuable logistical help, and an unparalleled meal or two were Eugeen and Lisanne Blancquaert-Dhaene. The people living in the Dominican Republic are as generous with their time and belongings as those that rushed out meals to Columbus and his sailors at their first meeting.

The folks at Indiana University are equally as supportive. My research relied heavily on the instruction and advice of Jon Fong, Lisa Pratt, Arndt Schimmelmann, and the other members of the Biogeochemistry Laboratory in the Department of Geological Sciences. They offered their instruments and guided my efforts to make them work. In much the same way, Susie Bernhardt, Marcie Covey, and Debra Wilkerson of the Department of Anthropology shepherded me through the wilds of the university system which not only allowed me to graduate in a timely manner, but made that time spent in Bloomington more fun and productive.

This dissertation was written during the year I was supported by the J. Stewart and Dagmar K. Riley Graduate Fellowship. This grant allowed me to split my time and energy solely between documenting the research and playing with my son, Benjamin. While he was slightly disappointed the resulting book was not of the quality of *How to Eat Fried Worms*, he and I both appreciated the time together when I was not writing. The artifacts were collected during travel funded in part by the Center for Latin American

and Caribbean Studies, Sigma Xi, the David C. Skomp Fellowship Fund of the Department of Anthropology, the University Graduate School, and other sources.

I would like to especially thank my dissertation committee members for shedding some light to aid in the academic blindness associated with Columbus scholarship. Simon Brassell, Anne Pyburn, and Rick Wilk helped form the good parts of this paper. Geoff Conrad provided all the encouragement and financial backing a graduate student could ask of their mentor and then gave more. My wife, Jennifer, was not a formal part of the committee, but she too was forced to read every word. She edited the manuscript, challenged my assumptions, and made me explain the research in a much better way. The final result would have been even less understandable without their input.

Unfortunately, I am not able to name all those who helped me during the research and writing of this work, but I owe a debt of gratitude to each and every person who funded, dug, explained, or read. By using their money, assistance, and advice in the best way I knew how, I hope that my dissertation can serve as a first installment on that debt. In some small way, my research may begin to pay back society by increasing our knowledge about the way people in the past interacted and borrowed ideas from each other.

ABSTRACT

James M. VanderVeen

SUBSISTENCE PATTERNS AS MARKERS OF CULTURAL EXCHANGE: EUROPEAN AND TAÍNO INTERACTIONS IN THE DOMINICAN REPUBLIC

Although the stories of Christopher Columbus's voyages to the New World are well known, the daily life of his sailors and the indigenous people they met are not as clearly understood. This research investigates the reciprocal influence of cultures in contact through an analysis of a basic element in the lives of these people: food. Although documentary records and paleoenvironmental studies can explain which plants and animals were gathered, these sources suffer from biases. For instance, at the site of La Isabela in the Dominican Republic, European chroniclers were motivated by specific agendas colored by pride, cultural superiority, and salesmanship. They rarely recorded the activities of any but the elites of either the colonists or the Tainos encountered there. Also, because the faunal and floral remains are often poorly preserved or statistically inconclusive, an archaeological reconstruction of the typical diet is less than accurate.

To learn more about the interactions between the native people and the explorers, comparisons were made of domestic ceramic artifacts and the associated food residue recovered from the La Isabela colony and the surrounding indigenous villages. Further, absorbed organic residue analysis is employed to resolve many questions surrounding the

interactions of cultures in such an unprecendented arrangement. The method uses gas chromatography - mass spectrometry to identify the preserved organic molecules extracted from within walls of domestic pottery. By evaluating specific fatty acids and lipid constituents from both native and colonial ceramics, the research distinguishes broad food categories as well as various families of plants and animals that were consumed. Contrary to the established paradigm which holds that the Spanish starved and the indigenous people were completely destroyed, the food residue reflects similar patterns of sustenance and vessel use between the groups, suggesting a more complex pattern of cultural exchange. While this method has its limitations, especially with regards to the reconstruction of cuisines exploiting a wide variety of resources and the recovery of residues from sherds deposited in tropical environments, the research can supply valuable information on the little understood dietary practices of colonists and their hosts.

TABLE OF CONTENTS

Section *Page*

ACKNOWLEDGEMENTS iv

ABSTRACT vii

LIST OF FIGURES xi

LIST OF TABLES xii

1. EXAMINING THE PROCESS OF CULTURAL EXCHANGE
   - Introduction 1
   - Research Objectives 2
   - Methods of Analysis 5
   - Chapter Previews 7

2. THE ENVIRONMENT FOR EXCHANGE
   - Introduction 10
   - Island Geology 11
   - Climates of the Old and New Worlds 13
   - Native Flora and Fauna 16
   - Introduced Species 22

3. THE CONTEXTS OF THE CULTURES AT CONTACT
   - Introduction 26
   - The People Who Met Columbus 27
   - Taíno Daily Life 30
   - The People Who Met Guacanagarí 33
   - Life at Sea 37
   - Repartimiento 40

4. PATTERNS OF CHANGE AND EXCHANGE AS SEEN IN THE PAST
   - Introduction 42
   - History of the La Isabela Area 44
   - Limitations of Previous Research 48
   - Potential of Present Project 51

5. RECONSTRUCTING SUBSISTENCE PATTERNS
Introduction....64
Sampling Criteria....65
Description of Sites....67
Artifact Documentation....75
Extraction Procedure....75
Experimental Controls....78
Non-destructive Protocol....79
Instrumental Analysis....81
Compound Identification....84

6. EVIDENCE FOR CULTURAL INTERACTION
Introduction....87
Results of GC-MS Analysis....88
Sources of Contamination....93
Preservation Potential of Various Samples....107
Outcome of the Non-destructive Protocol....110

7. SITUATING SUBSISTENCE IN THE CONTEXT OF CHANGE
Introduction....118
Distinguishing Different Types of Foods....119
Descriptions of Residues from Sites....123
Comparing Vessels, Cultures, and Food....150

8. SUMMARY AND CONCLUSIONS
Introduction....157
Objectives and Results....159
Practical Limitations....165
Research Possibilities....168

REFERENCES CITED....174

APPENDIX A
Description of Archaeological Samples....194

APPENDIX B
Characteristics of Samples Selected for Analysis....198

APPENDIX C
Organic Compounds Identified Within Samples....202

APPENDIX D
Criteria Used for Residue Identification....211

APPENDIX E
Curriculum Vita....215

LIST OF FIGURES

Figure *Page*

2.1 Map of the islands and mainland coastlines of the Caribbean Sea 12
2.2 Physical characteristics of Hispaniola 14

4.1 La Isabela and its environs 46
4.2 Chemical structures of lipids 59

5.1 Archaeological sites in northwest Dominican Republic 68
5.2 Archaeological sites in eastern Dominican Republic 74
5.3 Partial gas chromatogram of the total lipid extract of ISA 16 82
5.4 Mass spectrum of $C_{18:0}$ fatty acid 85

6.1 Chromatograms resulting from non-destructive protocol experiment (LEO 01 and LEO 02) 114
6.2 Chromatograms resulting from non-destructive protocol experiment (LEO 03 and LEO 04) 115
6.3 Chromatograms resulting from non-destructive protocol experiment (TAM 25a, TAM 25b, and TAM 25c) 116

7.1 Archaeological sites used in GC-MS analysis 124
7.2 Relative abundances of fatty acids in residues from Edilio Cruz 126
7.3 Relative abundances of fatty acids in residues from Loma de Leonardo 128
7.4 Relative abundances of fatty acids in residues from El Perenal 129
7.5 Relative abundances of fatty acids in residues from Punta Rucia 131
7.6 Relative abundances of fatty acids in residues from El Tamarindo 134
7.7 Relative abundances of fatty acids in residues from Las Coles 146
7.8 Relative abundances of fatty acids in residues from La Isabela 147

LIST OF TABLES

Table *Page*

2.1 Plants used by the Taíno in Greater Antilles as food....18
2.2 Animals used by the Taíno in the Greater Antilles as food....20
2.3 Foods documented as used by Europeans on the first two voyages....23

4.1 Specific and general sources of biomarkers used in residue analysis....54
4.2 Common lipids targeted in the analysis of organic residues....63

6.1 Fatty acids recognized through GC-MS analysis....92
6.2 Alcohols recovered through GC-MS analysis....93
6.3 Other compounds recovered through GC-MS analysis....94
6.4 Samples with significant presence of dehydroabietic acid....98
6.5 Relative percentages of fatty acids identified in sets of soils and sherds....106
6.6 Description of sherds used in the non-destructive protocol....112

7.1 Assignment of sample residues to food categories....151

CHAPTER 1:

EXAMINING THE PROCESS OF CULTURAL EXCHANGE

Introduction

Food is arguably the most basic and fundamental element of human existence. For that reason, research into patterns of subsistence has a long and storied career in the field of anthropology. But such studies are not limited only to the practical questions of which plants were gathered and how animals were processed. Scholars have also recognized that food can be used as a specific device in the examination of much broader, more complicated cultural issues (Brumfiel 1991; Harris 1987; Miller and Burger 1995; Wilk 1999). Similarly, just as the production of food became more sophisticated and complex over time, the analyses of ancient diets have advanced in intricacy and comprehension as well.

For example, research on ancient foodways may be used to discern the relationships of cultures in contact. While everyone must eat, there is a multitude of ways to get nourishment. It is expected that these methods would vary between two disparate groups at their initial meeting, since the parties would have no common history and sometimes would not share so much as a single plant native to both areas. Yet if one of the groups incorporates new culinary techniques within a very short time, this assimilation will present detailed data regarding not only the changing patterns of

subsistence, but also the informal daily interactions among members of the converging cultures. The study of a humble class of artifacts like domestic dishes can even provide information on such an important topic as the creation of a new way of life.

After all, the modern world, it can be said, was formed as Christopher Columbus met with the Taíno of the Caribbean (Todorov 1984). Although the stories of Columbus's voyages to the New World are well known (e.g., Colón 1992; Columbus 1989; Martyr D'Anghiera 1989; Morison 1942), the daily life of his sailors and the people they met are not as clearly understood. Although the explorers and the indigenous islanders had never before even considered the existence of each other, evidence produced at their meeting can explain more about the beliefs and organizations of these groups than if they had remained in isolation. It is through the interactions of cultures and societies that researchers can learn what traits and materials are seen as most important. By studying the artifacts that record the confrontation and cooperation between the parties, this research reconstructs an important and unprecedented instance of cultural exchange.

Project Objectives

There is actually little in the way of systematic archaeological investigation into the lives of the indigenous people of the Caribbean at the time of European contact (e.g., Deagan and Cruxent 2002a, 2002b; Keegan 1996; Rouse 1992). This is surprising because the Taíno were the first Native Americans to bear the full impact of the uniting of the Old and New Worlds. Sustained interaction between Europeans and the Taíno began during Columbus's second voyage with the founding of La Isabela on the north

shore of Hispaniola in January 1494. The pattern of European-Taíno interaction there, and across the Greater Antilles, is usually portrayed as brutal exploitation leading to rapid extinction. According to many experts, the Taíno were devastated by war and oppressive work in the colonial mines and plantations and were all dead by 1535 (Wilson 1990). More recently, biological anthropologists and medical historians have argued that Old World diseases were the primary cause of the Taíno extinction (Cook 1998, 2002; Lalueza-Fox, et al. 2001).

In reality, although the Taíno and their way of life may have been changed by the arrival of the Europeans, at least some indigenous people and their customs survived. Not all Caribbean islanders were enslaved by the conquistadores, as particular *caciques,* or chiefs, made political and military alliances with the new arrivals. Other Taíno may have survived long after 1535 by withdrawing, together with run-away slaves and the occasional rebel colonist, from areas of European control (Ferbel 2002; Guitar 1998; Joseph 1997). If this is so, then modern Caribbean society emerged very early from a complex sphere of multicultural interaction. Not enough is known about this period of contact to determine the exact circumstances of those affected by the collision of the New and Old World, Taíno and African alike.

The same can be said about the welfare of many European colonists as well. Firsthand accounts by the explorers celebrate the amount and variety of local foods available at La Isabela (Colón 1992). Chroniclers later state, however, that dwindling food supplies were a constant threat to the settlers (Oviedo 1959). These texts note the Europeans were insistent on maintaining their traditional foods, cooking processes, and utensils, even in the face of starvation. Although documentary records and current

archaeological research support the possibility that the hungry colonists did indeed avoid the plentiful resources available in the area (Deagan and Cruxent 2002a, 2002b), these sources may suffer from bias. The European chroniclers were motivated by specific agendas (including pride and cultural superiority), there is no record at all of the activities and behaviors of the non-elites of either cultural group, and because the site has been extensively disturbed, an accurate archaeological reconstruction of the fifteenth-century diet is problematic. The faunal and floral remains in the archaeological record are rare, poorly preserved, and otherwise inconclusive.

To account for such problems, some Caribbean archaeologists have used the physical attributes of pottery vessels to reflect domestic food use (Espenshade 2000). The current study continues such work by conducting a comparison of the vessel form and function of domestic ceramic artifacts recovered from both the La Isabela colony and the surrounding indigenous villages to learn more about the foodways of – and thus the interactions between – the native people and the explorers. Past studies seem to show the size and shape of a vessel corresponds with some confidence to its function (Curet 1997). In particular, domestic ceramic vessels have key attributes, such as rim diameter, presence or absence of handles, and base size and form, that reflect the desired use intended by its maker (Rice 1996). This has been supported by both ethnographic and archaeological data (Cusick 1991; Deal, et al. 1991). In an ideal situation, this may be enough data to reconstruct the use of the vessel in specific food production activities, but due to the severe and nearly instantaneous colonial impact on the native populations of the Caribbean, little in the way of complete and accurate ethnohistoric accounts are available with regards to the Greater Antilles at the time of contact.

Research Methods

Since faunal remains are scarce, ethnohistoric accounts are incomplete, and intact vessels are rare, the current research uses a technique known as "absorbed residue analysis" to aid in dietary reconstruction. Small ceramic sherds are pulverized and a solvent is mixed with the powdered pottery in order to remove organic molecules. After the compounds are extracted, their unique signatures are identified using gas chromatography-mass spectrometry (GC-MS), even resulting in the specific name of the particular plant or animal species processed in the vessel (Evershed, Charters, et al. 1995; Evershed, et al. 1999; Malainey, et al. 1999b). Thus, the technique, not yet widely used outside of Classical archaeology, has an appreciable effect on the resolution of many important questions regarding subsistence patterns. Moreover, the absorbed residues interact with the porous walls of materials such as unglazed ceramics over the use-life of the vessels, and consequently do not readily leach out of the ceramic during burial, nor are they destroyed by mild washing and long-term storage in plastic as is common after archaeological recovery (Heron and Evershed 1993; Heron, et al. 1991).

A research team from Indiana University has spent significant time in the La Isabela area conducting systematic surface surveys (VanderVeen 2005a) and excavations (VanderVeen 2005b). During this time, the remains of food production and storage vessels from both potential Taíno cooking pots and European domestic ware were collected. These ceramics were measured and their form evaluated in the field laboratory, after which they, and the other recovered artifacts, were curated locally. Since the Dominican Republic does not have accessible the necessary equipment for GC-

MS analysis, however, governmental permission was granted for a study sample to be transported to the Biogeochemistry Laboratories at Indiana University.

The new information accumulated from absorbed residue analysis (such as the presence of indigenous and/or foreign species of plants and animals), when pooled with the more traditional study of cooking vessel shape, construction, and distribution, provides for a sophisticated examination of the interaction between the representatives of the New and Old Worlds on a focused domestic scale. The same archaeological evidence is also used to show if the design, manufacture technique, and scale of production of certain ceramic artifacts within the Taíno repertoire were modified as a direct result of the interaction with the colonists. Specific items may have been altered due to trade preferences, others may change to reflect efforts of assimilation or resistance, and still more could be selected for by shifts in subsistence strategies. By means of an examination of the cultural material, this research examines the dynamics of how both the Taíno and Europeans reacted to the presence of a new and different people.

Such a concrete archaeological analysis is significant in that it provides another line of evidence on the cultural interactions. Besides precious metals, of which there only small amounts found near La Isabela, scholars know little about what indigenous goods and practices the Europeans found valuable or even tried to employ. The presence of indigenous cooking techniques, if not the Taíno pots themselves, is hypothesized to be found within the colonial assemblage. Evaluating what objects and behaviors the people of the two cultures purposefully gathered from their counterparts, whether for use in common domestic chores or simply as curiosities, should allow for the development of a model of cultural exchange between the parties. Based on the materials collected, and

what ideas were adopted, the aim of this study is to provide a fuller perspective on the behaviors of cooperation and conflict. The archaeological indicators of daily practices, in combination with the historical record written by the Europeans, allows for a more accurate reconstruction of this unique cultural interaction.

If, contrary to previous notions, the colonists quickly adopted the staple foods of the Taíno as well as their production methods, then the interactions between the two groups were indeed more complex than that of conqueror and conquered. Alternatively, if this hypothesis is not supported, that information will also prove to be beneficial as it may provide evidence to substantiate the current assumptions of many scholars who suggest the groups were quite isolated culturally (Chiarelli and Luna Calderón 1987; Deagan and Cruxent 2002a, 2002b). Regardless of the result, the knowledge gained from this original research will add to both the theory of culture change and the methods of reconstructing subsistence patterns.

Chapter Previews

The geology, flora, and fauna of the research area are described in Chapter 2. The climate of the Dominican Republic is contrasted to that found in Spain, the country from which most of the colonists came. By providing a natural context to the cultural behaviors, one can begin to see why different foods may have been used in various areas. The cultural contexts of the people making contact are considered in Chapter 3. Here the current knowledge regarding the economic and social structures of the two groups are briefly summarized so as to better gauge the motivations behind chosen subsistence patterns.

Chapter 4 includes a review of previous archaeological work conducted in the research area and explains why the technique of absorbed residue analysis may help in reconstructing the behavior of the inhabitants. Additionally, the theoretical foundation of the methodology is summarized, supplying the rationale behind the selection of protocols used. Then, in Chapter 5, the specific techniques used in residue extraction are outlined. Criteria are given for the selection of sherds, archaeological sites, and various instruments employed in the investigation.

The results of the gas chromatography and mass spectrometry analysis are presented in Chapter 6. The extracted lipids are defined, quantified, and tabulated. These data are then evaluated and compared in Chapter 7. The results are used to examine different patterns in behavior and decision-making. Problems arising from this approach are also noted.

Finally, Chapter 8 synthesizes what was learned during the course of this research. The benefits of absorbed residue analysis are assessed, and future directions are suggested. This new technique can offer information that is different from that obtained through other methods already practiced by archaeologists. The research used here should encourage other scholars working in the area to examine their own questions regarding subsistence patterns. Whether they are studying the importation of particular flora to a region, the ingestion of substances for medicinal or ritual practices, or the shifting behaviors of marine versus terrestrial resource exploitation, the analysis of absorbed organic residue can strengthen current interpretations.

Further, the methods used also have the power to resolve some ethical dilemmas faced by the discipline of archaeology. By extracting evidence of vessel use from small

pottery fragments that have been excavated previously, a researcher can make more efficient use of the non-renewable resource that is an archaeological site. Although the cost of using modern instruments to conduct GC-MS is not minimal, neither is the outlay in terms of excavation labor and time. Making additional use of material that has already been removed from a site saves the need to excavate others, thereby preserving precious resources.

CHAPTER 2:

THE ENVIRONMENT FOR EXCHANGE

Introduction

If it is true that "you are what you eat," then a description of the foods available to the original and colonial occupants of the Caribbean islands ought to be offered. This chapter outlines the flora and fauna present in the Greater Antilles at the time of contact, as well as the other components of the ecosystem. There was a wide variety of resources from which to choose, but not all species were utilized. The best way to understand the decision-making process of the people in the area, whether European or indigenous, is to first understand from which options these choices were made and how the local environment influenced the plants and animals present.

Islands present special circumstances in terms of ecological patterns. The plant and animal species are affected by their isolation, but also by the multifaceted interactions caused by the surrounding water and atmospheric conditions. Each of these elements adds to the complex nature of the Greater Antilles; this is no simple land, set apart from the rest of the world, in terms of the people and their surroundings. In fact, the introduction of flora and fauna to the different islands remains controversial even now (Hedges 2001), as do the circumstances of the first peopling of the area (Rouse 1992; Wilson 1997b). The connection between people, the land, the sea, and plants and animals

is dynamic and constantly changing, with each variable impacting the others within this web of life.

Island Geology

The islands of the Caribbean lie, for the most part, in an arc that stretches from the northern shore of the South American continent to the Yucatan Peninsula of Mexico (see Figure 2.1). Parts of this region are among the oldest and most multifaceted physiographic areas of Middle America (Moya Pons 1998). Curving northward from the coast of Venezuela are the volcanic chains of the Lesser Antilles. They, in turn, are linked to the Greater Antilles (comprised of the islands of Cuba, Jamaica, Hispaniola, and Puerto Rico), which are the tops of several underwater mountains and ridges attached to the Central American mainland. The body of water they enclose is the warm and relatively calm Caribbean Sea.

The Greater Antilles are characterized by a series of rugged mountains and deep valleys, none more so than the island of Hispaniola (West 1989). The modern nations of Haiti and the Dominican Republic occupy the west and east portions, respectively, of the island. Hispaniola occupies more than 76,000 square kilometers (Newsom and Wing 2004), or roughly the area of Vermont, New Hampshire, and Massachusetts combined. More than half of the island is dominated by four steep-sided highland ranges running northwest-southeast (Boswell 1989). The mountains are separated by broad, fertile valleys and bordered by coastal plains.

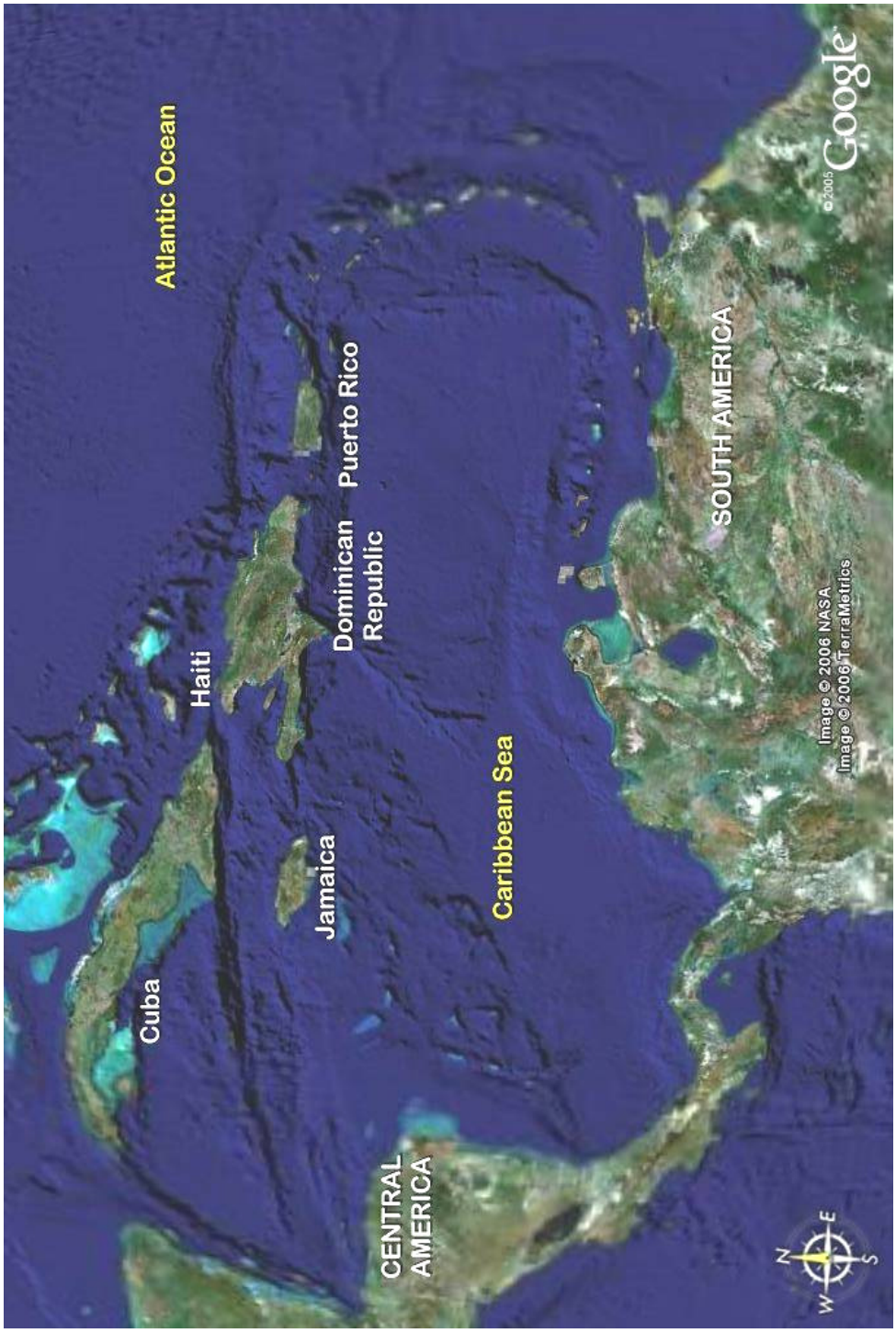


Figure 2.1 Map of the islands and mainland coastlines of the Caribbean Sea.

The varied topography allows for a multitude of ecological niches (see Figure 2.2). The northern coast has parallel ridges, the Cordillera Septentrional, interspersed with areas of the Atlantic Coastal Plain. South of the Cordillera Septentrional is an extensive plain known as the Cibao Lowlands. This is one of the most fertile areas in all the Caribbean (Boswell 1989) and has been an area of agricultural production and subsequent population concentration both before and after the period of contact. Unfortunately for the farmer, the word *cibao* means "stony" in the Taíno language (Colón 1992). South of the Cibao is the Cordillera Central, the primary mountain range of the island. Peaks here rise as high as 3000 meters, the tallest in the Caribbean.

On the southwestern flank of the Cordillera Central are alternating ridges (the Neiba-Martín García-Mateux-Noire Ranges and the Cordillera Meridional) and dry lowland troughs. Among these valleys is the Enriquillo – Cul-de-Sac depression, portions of which are below sea level and others are covered by large salt lakes. To the southeast of the Cordillera Central is the only sizeable stretch of coastal lowland on the island. The Caribbean Coastal Plain is a mixture of rich soils and dry scrub forests, depending on where the rain shadows form and the elevation of the land.

Climates of the Old and New World

The varied topography of Hispaniola is a primary cause of its equally complex climate. Although the island is within the tropical latitudes (it lies less than 20° north of the equator), temperatures are moderated by trade winds and elevation. The average temperature near sea level is around 26° C throughout the year. In the many mountain ranges, however, it can be cooler. The temperature decreases an average of 0.6° C

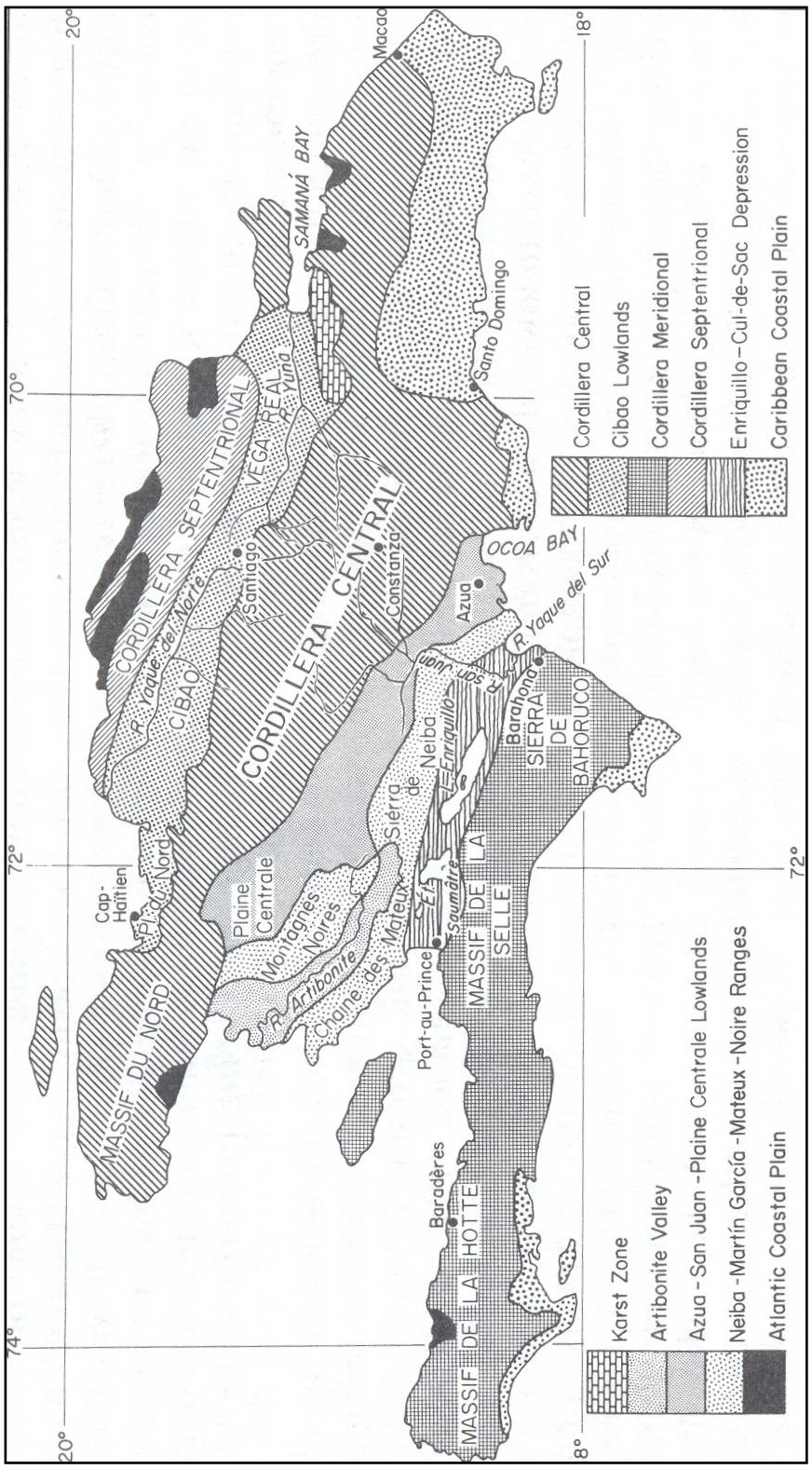


Figure 2.2 Physical characteristics of Hispaniola (after Boswell 1989).

Per 100 meters in elevation (Blume 1974). Winter temperatures can drop to near freezing at night in the higher mountains.

Precipitation also varies across the island. The average annual rate is between 100-150 centimeters, but some areas are tropical rain forests whereas others are deserts. There are two distinct rainy seasons for the north and south halves of the island, due to the atmospheric disruptions caused by the mountains (Moya Pons 1998). In the north, the rainy and cool months occur in the winter, and the soils dry up in the summer. On the other hand, the south is dry in the winter because the humidity is diverted northward. The summers in the region have hot and humid conditions, though, with regular afternoon showers. Separate microclimates exist within these areas depending on elevation and from windward or leeward exposures.

The same winds and water currents that cool the tropical heat and bring needed rainfall also carried the European ships across the Atlantic Ocean to the Caribbean. The geographical position of Spain allowed its sailors to take full advantage of the northern hemisphere's two primary wind systems: the Northeast Trades and the Prevailing Westerlies (Crosby 1986). But since the point of departure for Columbus's ships, in Andalusia region of the country, lies on the same latitude as central Virginia, the sailors had to acclimate to the conditions in the Caribbean. More importantly, so did their domestic animals and crops.

The climate in the temperate Andalusian region is cooler and drier than that of the West Indies, and it has a much greater range. Conditions run from an average of 6° C in the winter to 23° C in the summer. The precipitation in the area is much less rainy than

conditions in the West Indies, ranging from less than 25 centimeters to slightly more than 75 centimeters of precipitation a year, depending on the specific location.

Native Flora and Fauna

The geographical and climate patterns in the West Indies affected the diet of the Taíno, and their subsistence choices changed with the seasons. One food, however, was available throughout the year (Keegan 1992). Manioc (*Maniot esculenta,* also known as cassava) was the staple crop of the Taíno. It is a perennial woody shrub with a cone-shaped starchy root. The plant is hardy and withstands poor soils and drought conditions. Once mature, it can be left in the ground for up to two years without decaying (Dufour 2003), but the freshly harvested plant deteriorates quickly. It has an unsurpassed ability to recover from lost foliage due to damage or disease, and it is among the most productive plants with regards to the yield of carbohydrates produced per acre (Dufour 2003). Bartolomé de las Casas, an early colonist and priest with long experience in Hispaniola, claims that twenty Taíno men working six hours a day for a month could produce enough manioc to feed 300 people for two years (Sturtevant 1961). This may be an exaggeration, but it suggests that the indigenous foods and methods employed for growing them were successfully adapted to the environment.

Manioc was grown in garden plots, or *conucos*, that were cleared from the forest using a slash-and-burn technique. The crop was then planted in *montones,* small mounds of loose earth and organic compost, using a sharp, fire-hardened stick. The conuco system was an efficient response to the ecological conditions of the Greater Antilles. The heaped soil was well aerated, and the placement of the mounds reduced erosion and

increased yields even on the mountain slopes that characterize the islands. After harvest, replanting could occur on a continuous basis. Unlike protein-producing plants, manioc does not quickly deplete the soil of nutrients.

The leaves and roots of manioc are resistant to pests, but also to human consumption in their raw form. Throughout the plant are toxic levels of cyanogenic glucosides, which produce hydrogen cyanide when exposed to air. The poison requires extensive processing to be removed. By soaking the plant in water, cutting it into small pieces, or mildly heating it, a naturally occurring enzyme called linase comes into contact with the cyanide and liberates it into the air. The method used by the Taíno often involved grating the raw root and then squeezing the paste in a *cibucán* or *matapie*, a type of woven sack, to remove the toxins (Olazagasti 1997). The resulting manioc pulp is then dried and used as a flour to make the flat bread known as *casaba*. The juice, now also free of poison, serves as a base for pepper pot stew or manioc beer. The reward for the effort given to processing is the casaba bread with its long shelf-life and the useful manioc juice (Roosevelt 1980).

A continuous diet consisting solely of manioc, even in all its varieties and with its beneficial properties, would not be complete without additional supplement. The Taíno were sophisticated in their use of multi-level plantings in the fertile soils of the montones. Taller species would shade the more sensitive lower plants, and the ground cover produced by several desired species sowed together would crowd out unwanted weeds. Maize (*Zea mays)* was grown, often in the same montone, and roasted as ears or made into flour. Other plants (see Table 2.1) were cultivated in the conucos: beans (*Phaseolaris* sp.), chili peppers (*Capsicum* sp.), peanuts (*Arachis hypogaea*), squashes

(*Cucurbita* sp.), and sweet potatoes (*Ipomoea batatas*). Domesticated herbs and grasses included false mallow (*Malvastrum* sp.), goosefoot (species within the family Chenopodiaceae), passion flower (*Passiflora* sp.), prickly pear (*Opuntia* sp.), purslane (*Portulaca* sp.), star grass (*Hypoxis* sp.), trianthema (*Trianthema portulacastrum*), and panicoid grasses.

Table 2.1 Plants used by the Taíno in the Greater Antilles as food.

Fruits	***Vegetables***	***Grains/Seeds/Nuts***	***Tubers/Starches***
Candle berry	Anamu (Phytoloccaceae)	Achiote	Arrowroot
Cocoplum	Avocado	Cashew	Coontie (cycad)
Genip	Bean (Fabaceae)	Goosefoot	Manioc
Genipap	Bean (Phaseolus)	Maize	Sedge (rhizome)
Guaba	Chili pepper	Panicoid grass	Sweet potato
Grape	Epazote/Lamb's quarters	Peanut	
Guava	Horse purslane	Trianthema	
Hog plum	Mallow (Malvaceae)		
Mamey	Passion flower		
Mastic bully	Purslane		
Mulberry	Squash		
Papaya	Star grass		
Pineapple			
Prickly pear			
Raspberry			
Sapodilla			
Sea grape			
Soursop			
Star apple			
West Indian cherry			

(from Fortuna 1978; Newsom and Wing 2004; Sauer 1966; Sturtevant 1961)

When the conucos would no longer produce crops at the same rate due to the depletion of soil nutrients, they were converted to tree crop production or left fallow, and new fields were created. Closer to the houses in the Taíno villages were smaller garden

plots with plants from which fewer quantities were gathered at one time, or that required closer attention (Keegan 2000). Such species may have included various spices, medicinal plants, and those used for religious practices. Fruit trees were also planted in the vicinity. These are the tropical delights that come to mind today when one thinks of the Caribbean, and they were noted with enthusiasm by European chroniclers (Las Casas 1989; Oviedo 1959). It would be common to find cocoplum (*Chrysobalanus icaco*), genip or Spanish lime (*Melicoccus bijugatus*), genipap (*Genipa americana*), guava (*Psidium guajava*), mamey (*Mammea americana*), papaya (*Carica papaya*), or soursop (*Annona* sp.), among others.

The Taíno had a mixed subsistence economy of horticulture and hunting-fishing-collecting. While there was a wealth of fruits, vegetables, starches, and spices available, the land fauna is extremely poor when compared to Central or South America (Blume 1974) (see Table 2.2). The only widespread terrestrial mammals present in the Greater Antilles at the time of contact were bats, dogs (*Canis familiaris*), shrew-like insectivores (*Solenodon* sp. and *Nesophontes* sp.), and rodents known as cony (*Geocapromys* sp.), guinea pig (*Cavia porcellus*), and hutía (*Isolobodon portoricensis*). The hutia was the most common managed species in Hispaniola, Puerto Rico, and the Virgin Islands. Dogs were the most prevalent domesticated animal, and some have even been found buried together with human skeletons in a ritual context (Newsom and Wing 2004). They were probably used for hunting rodents and as companions as well. Guinea pigs have been recovered from an elite ceremonial center at Tibes, Puerto Rico, suggesting a particular use in Taíno culture (deFrance in Newsom and Wing 2004).

Table 2.2 Animals used by the Taíno in Greater Antilles as food.

Terrestrial Species		*Aquatic Species*	
Vertebrates	***Invertebrates***	***Vertebrates***	***Invertebrates***
Anole	Hermit crab	Crocodile	Bivalve (clam, oyster)
Bat	Insect	Fish, estuarine (mullet, snook)	Crustacean
Bird (duck, pigeon)	Land crab	Fish, pelagic (herring, tuna)	Gastropod (conch, limpit)
Cony	Land snail	Fish, reef (grouper, parrotfish)	
Dog	Spider	Frog	
Guinea pig	Worm	Manatee	
Hutia		Monk seal	
Iguana		Porpoise	
Toad		Shark and ray	
West Indian shrew		Turtle	

(from Fewkes 1907; Keegan 2000; Newsom and Wing 2004; Wing and Reitz 1982)

Other animal species include crocodiles (*Crocodylus acutus*), iguana (*Cyclura cornuta*), land crabs (*Cardisoma* sp.), small lizards (e.g., *Anolis* sp.), and land snails (*Caracolus* sp.). A few birds were domesticated, such as Muscovy ducks (*Calrina moschata*) and parrots (*Amazona* sp.). Although both species were discussed in the European chronicles, parrots were not directly mentioned as a food source. Instead, they were kept for their plumage.

As one may expect on and around relatively small islands, the number and variety of animals present in the sea and rivers far exceeds those found only on land (Blume 1974). This is seen clearly in the archaeological record. The primary fauna collected from Taíno sites are the various aquatic animals (Wing and Reitz 1982) (see Table 2.2). In many samples, 80 percent or more of the identified bones or shells are from marine creatures (Keegan 1986; VanderVeen 2005b; Wing 1974). Marine fish comprise a large portion of this assemblage.

The Taíno exploited all the separate niches, from river estuaries and mangrove swamps close to shore to the coral reefs and deep water further out into the sea. They used hooks fashioned from bone or shell, nets woven from palm fibers or cotton, and harpoons to gather their prey. More unique methods included driving the fish into a system of weirs where they were kept alive until needed or adding a stupefying chemical derived from plants to the water in order to stun the fish to the surface (Rouse 1992). The chronicles report the Taíno would even tie lines to an eel-like remora, which would then seek out larger fish to which to attach itself (Colón 1992). The two fish would be hauled in, and the process repeated. At times, their techniques were so successful that the reefs and shoreline environments became over fished (Russ 1991; Wing and Wing 2001). The Taíno would simply respond by moving to new fishing grounds until the previous one recovered.

The indigenous islanders could also take advantage of the other resources available to them, as the waters of the Caribbean teem with life. The bones of manatee (*Trichechus manatus*), marine turtles (of the family Chelonidae), monk seals (*Monachus tropicalis*), and porpoises (from the Delphinidae family) have been recovered from archaeological sites in the Greater Antilles. Smaller animals such as crustaceans, bivalves, and gastropods (especially the queen conch, or *Strombus gigas*, whose shell was also used in tool production) are found in great numbers at almost every excavation (Keegan 2000; Wing 2001).

Introduced Species

The European colonists could not have predicted the wealth of food sources that would be available to them on their arrival in the Caribbean. Columbus and the other ships' captains were experienced sailors and made sure to have provisions stocked on board for any circumstance. The supplies taken on the second voyage, in 1493-1494, were meant to support the colonists only until their first crops could be planted and harvested. The plan for colonies was to recreate Iberian subsistence patterns abroad without any thought toward adopting indigenous behaviors (Crosby 1986; Deagan and Cruxent 1993; McEwan 1995), although this may have changed later in the colonial process (Rodríguez-Alegría 2005). They brought along the necessary seeds and fruit stones to replicate the staff of life for the 15th century Spaniard: wheat bread, olive oil, and wine (Crosby 2003). Other plant supplies included barley (*Hordeum vulgare*), garbanzo beans (*Cicer arietinum*), lentils (*Lens culinaris*), and sugar cane (*Saccharum officinarum*). Meats that were prepared for long travel, like bacon and dried cod, were also stocked. For a full list of European crops and livestock, refer to Table 2.3.

On their arrival to the islands, the chroniclers delighted in the abundance of wild fruit, the rich seafood, and the cultivated plants brought to them by the Taíno, but they also had bad experiences with the novel flora and fauna. A personal physician of King Ferdinand and Queen Isabella accompanied Columbus on his second voyage and reports on the result of some Europeans impulsively trying the fruit of one tree: "…no sooner did they taste them than their faces swelled, growing so inflamed and painful that they almost went out of their minds" (Chanca in Cohen 1969:132). Further, many of the Old World

Table 2.3 Foods documented as used by Europeans on the first two voyages.

Native Species		*Introduced Species*	
Plants	***Animals***	***Plants***	***Animals***
Arrowroot	Agouti	Almond	Cattle
Avocado	Bird (duck, pigeon)	Barley	Chicken
Bean	Bivalves (clam, oyster)	Bean	Fish (salt cod)
Cashew	Crustacean (lobster, shrimp)	Cucumber	Goat
Chili pepper	Dog	Date	Pig
Corn	Fish (mullet, salmon)	Garbanzo bean	Sheep
Genip	Hutia	Garlic	
Hog plum	Iguana	Grape	
Maize	Manatee	Lentils	
Mamey	Monk seal	Lettuce	
Manioc	Ray	Olive	
Peanut	Turtle	Onion	
Pineapple		Radish	
Sweet potato		Rice	
Wild grape		Spring melon	
		Sugar cane	
		Wheat	

(from Colón 1992; Las Casas 1989; Morison 1942)

crop seeds spoiled before planting or did not adapt to the tropical environment and soils. Columbus requested more supplies from Spain within a month of arriving at La Isabela.

Sugar cane (*Saccharum officinarum*), as one can tell by visiting the islands today, was tailored to the conditions of the Caribbean and thrived. Bananas (*Musa* sp.) and plantains (*Plantago* sp.) brought later from the Canary Islands were an immediate success. So too were the introduced animal species of cattle (*Bos taurus*), pigs (*Sus scrofa*), and rats (*Rattus* sp.). The latter was unintentional, but no less successful. These animals filled a niche that had no competing or predatory species on the islands, and they did so well that after 1503 it was no longer necessary to import any horses, pigs, or cattle

from Europe (Augelli 1989). Still, in a vain effort to become self-sufficient in familiar foods, the settlers planted Old World cereals and vegetables time and again, only to see them wither in the fields. That is, when they were farmed at all: most of the attention of the colonists was turned toward the search for gold and the construction and maintenance of their military complex.

Columbus founded La Isabela after he discovered his initial attempt at European-Taíno relations did not work. Because the *Santa María* had grounded and wrecked, some of the men of the first voyage were left behind at La Navidad, an outpost further west along the northern shore of Hispaniola. In the intervening year of Columbus's absence, those men were killed, most likely by angry Taíno men protecting their wives. With this incident still fresh in their minds, the Europeans were probably suspicious and a bit fearful of the indigenous islanders. They were understandably hesitant to dine on unfamiliar items that may be poisonous and were prepared quite differently from that which they understood from their own kitchens (McNeill 1991). Columbus wrote of the trees he saw in the West Indies: "[they are] as different from ours as day from night, and so the fruits, the herbage" and even the rocks (in Crosby 1991:76). It was with some hesitation then that the hungry colonists tried the local foods (see Table 2.3). They eventually requested casaba from the Taíno as tribute (Sauer 1966), and it was one of their primary foods on the ships returning to Spain (Colón 1992).

For the most part, however, complaints of starvation and illness aggravated by hunger were constant (Deagan and Cruxent 2002b). According to the historical accounts, it appears that the colonists did not consider supplementing their diet with the shellfish, fruits, and other foods used by the local people. Nor is there evidence of significant

European utilization of native flora and fauna species in the archaeological records of the earliest colonial sites (Deagan and Cruxent 2002a; Ewen 2000; Newsom 1993). This decision may have been one of cultural pride. In fact, the typical Taíno staples of manioc and locally gathered fish and shellfish are viewed with some disdain and prejudice as the fare of the lower class by many in the West Indies even today (Newsom and Wing 2004). Or it may have been that the food was eaten but did not satisfy psychologically because colonists were still "starving" for their more recognizable foods from home, a condition reported in the 16th century Spanish colonies of North America (Reitz and Scarry 1985). Either way, the aversion to indigenous subsistence patterns appears to have contributed to the deaths of many of the original Europeans in the New World. Less than five years after the founding of La Isabela, more than one-third of the settlers who arrived at the town had died (Moya Pons 1998).

CHAPTER 3:

THE CULTURAL CONTEXTS AT THE TIME OF CONTACT

Introduction

When Columbus and his fleet arrived in the West Indies for the first time, they found a very complex society. Although it did not have the scale of the Inca Empire of which Pizarro would soon be in awe, or the scope and intensity of the Aztec that Cortés would shortly encounter, the involved social and economic practices of the Taíno fascinated the visitors. The Native Americans of the Caribbean had a rich and dynamic culture, alien to that of the Europeans, but in many ways, similar: they lived in well-organized towns, cultivated fields, fished and hunted, played games, created beautiful art, performed rituals in a yearly cycle, worshipped powerful gods, followed their leaders most of the time, and fought battles on behalf of those leaders against others. This was not unlike what people were doing back in Europe at that time.

In the same way, the Taínos recognized aspects of the European way of life. The sailors were hungry for fresh food, devoutly religious to a variety of supernatural powers, gave gifts to their hosts, and so on. Although the indigenous people left no written records to document their view of the strangers, one can assume the ships coming over the horizons were startling. Still, as soon as the Europeans made landfall, they were quite often met with offers of food and other items of value. The sailors were presented with

many materials that among the Taino could only be given to the highest-ranking caciques. It could be argued that this is what the Taino thought the Europeans were – elites from lands they did not know and thus potential allies against rivals in the area. Or they could have been seen as gods, spirits of the dead, and most correctly, portents of doom.

This chapter will discuss the people involved in this meeting of two worlds. There is some confusion regarding the terminology and cultural composition of the native islanders at the time of contact, and this will be addressed. Likewise, a section will resolve the common misunderstandings regarding Columbus and the sailors that joined him. The daily lives of the Taíno and the Europeans will then be outlined, setting the stage for their actions at contact. Finally, the fateful aftermath of the contact between the two groups will be briefly considered.

The People Who Met Columbus

When Columbus first met the people living in the Greater Antilles, he probably gave them the generic name "Indians" because he thought his ships had landed on the lands east of the Indian Ocean. These people lacked a name describing their overall cultural group at the time of contact for a number of reasons, not the least of which was the lack of a need for such a term. Like many groups around the globe, they saw themselves as "the people," and had no requirement to come up with labels that would be understood by the Europeans and fit into their Western worldview. They did have terms for the people to whom they were not related or whom they saw as other than themselves,

but they referred to themselves by the area in which they lived (Rouse 1992). This can, and did, change over time.

Moreover, the Greater Antilles were inhabited by more than one group, even if their material culture had substantial similarities. This confused the European chroniclers, and some tended to describe most of those they met as one people (Oviedo 1959). Few of the sailors could understand the languages they heard and could not see the cultural mosaic that existed even within the small islands. The information that was collected from the various groups often fails to describe the original source and makes no indication of the specific society to which it refers (Curet 2003). The Europeans also had other matters, like gold, on their minds and thus did not view conducting an exacting ethnography as a priority.

Following the practice of other archaeologists working in the area (especially Rouse 1992), the separate but related societies in the Greater Antilles at the time of contact will be referred to here as the *Taíno*, a word that means "good" or "noble" in their language. This is the term that the islanders offered to the Europeans when describing themselves. It was not given as the name of their culture, however, as much as a way to distinguish themselves from the Island Caribs of the Windward Islands in the Lesser Antilles. The Island Caribs have been saddled with a reputation of being warlike and cannibalistic. This characterization is most likely an artifact of early and unsophisticated ethnohistories, an uncritical reading of the chronicles, and a campaign by the Taíno to portray others in the area as dangerous foes.

To add to the confusion of names, the Taíno belonged to a language family known as *Arawak* (Rouse 1987), which is also the name of a cultural group whose

members live around the mouth of the Orinoco River in Venezuela and in the coastal island of Trinidad. Although linguistically related, the Taíno and Arawaks shared about as many cultural traits and vocabulary words as do the French and Spanish, who both speak a Romance language. To make matters more confounding, while there may have been a universal language of sorts on the island of Hispaniola (Pané 1999), people in different regions may have had distinctive dialects (Wilson 1990).

Other names for the people of the Caribbean are often seen in the ethnohistorical and archaeological literature. These include the *Ciboney*, *Ciguayo*, *Macoríx*, and *Lucayan*. The Taíno used specific terms to distinguish various subgroups living is certain areas, and these were translated as accurately as possible into Spanish. The former term describes the possibly imaginary people who lived in eastern Cuba and the latter refers to the people of the Bahamas (see Keegan 1992). Ciguayo and Macoríx confusingly denote either two separate ethnic groups or two names for a single group in the northeast region of Hispaniola (Wilson 1990). In either instance, these people were seen as different from the rest of the Taíno on the island, with a mutually unintelligible language.

Archaeologists have also divided these people into even more categories based on the way they made and decorated their ceramics, an artifact class that is among the best preserved over time and thus found often at sites. At the time of contact, all the Taíno ceramics were of one major style: the Ostionoid series (Rouse 1992). But within that series were a number of subseries. The styles present in Hispaniola were primarily *Meillacan*, recovered from the Cibao Valley as well as west toward central Cuba and south to Jamaica, and *Chican*, found mostly in villages along the southern Caribbean Coastal Plain across the Mona Passage to the east and into Puerto Rico. Meillacan

pottery is associated primarily with the Macoríx while the other Taíno on the island, possibly including the Ciguayo, created vessels in the Chican style.

While people are more than just manufacturers of pottery, artifacts are commonly used as a proxy for cultures and often employed to distinguish groups that existed in the past. Many archaeologists have fallen into the trap of making the sherds into the subject of study rather than the creators of the vessels from which those sherds are derived. The reality of how people identified themselves is certainly more complex than "one pot, one group." For instance, there was likely trading or intermarriage between the people of all the groups, as evidenced by sherds from different decoration styles found within the same site and even during excavations of stratigraphic levels only 10 centimeters deep (VanderVeen 2005a). With a close geographic proximity and frequent exchange of items, the people probably had close relationships and were more similar than previously thought, if they were separate cultures at all.

Taíno Daily Life

Regardless of all the possible language, cultural, or ceramic differences between anthropologically defined classes, the indigenous people in Hispaniola lived in much the same way. The population was organized into chiefdoms, perhaps five or so at the time of contact (Wilson 1990). The paramount chief could be male, known as a *cacique* (from the Taíno word "kacike"), or female, called *cacica*. They controlled a number of district chiefs, who in turn headed a loose organization of village chiefs in their area. As one can imagine, there were rivalries between chiefs at all levels. Power was maintained through military and political skill and depended on keeping widespread relations loyal. Sons and

daughters would be shuttled about to other residences as was politically expedient following the pattern of avunculocality, where lineage is traced through the brother of one's mother (Keegan 1992).

One cacique is reported to have assembled 300 chiefs who all answered to him (Wilson 1990). If this is indeed the case, then a head of large family or very small village could be seen as a chief. Most of the population resided in permanent villages of varying size. The cacique would have a large home with a central plaza in front. The rest of the houses, constructed in circles of wood and thatch, would be irregularly positioned around the plaza. These structures were said to be spacious enough to hold a large extended family (Sauer 1966). Inside the houses, goods were hung from the walls and hammocks were used for sleeping.

The plazas in the village were rectangles of cleared terrain with earth embankments or stones surrounding the outside edge. They were used as places to meet and as dance floors for celebrations denoting events like a chief's marriage or passing, the conclusion of a battle, or a particular time of year. A plaza may have also served as a ball court. Much like the Mesoamerican ballgame practiced by the Maya and Aztecs, the Taíno *batay* was a game in which a rubber ball was passed back and forth among the participants without the use of hands or feet. All members of the society could play, and it was a popular pastime. It was also a symbolic representation of warfare between chiefdoms, as suggested by the locations of the biggest courts on the borders between the regions controlled by different caciques (Alegría 1983; Wilson 1990).

It is unknown if the daily activities within the village were directly organized by the cacique. It is more likely that he or she was principally responsible for the planning

of larger and more long-term events like storage and redistribution of surplus foods and arranging trading expeditions between islands. Most of the food gathering and harvesting was done by the women of the village at their discretion; the men would hunt, fish, clear the fields, and raise the conucos. (The subsistence patterns of the Taíno were discussed in-depth in Chapter 2.) Women also made most of the ceramics and did the weaving.

Any items that could not be collected or created locally were obtained through trade. As much of their food came from the sea, the Taínos were adept at navigating the open ocean. In fact, as is the case in many island communities, the connection between people from across water passages was often closer than that with groups on the same island. The Mona Passage between eastern Hispaniola and western Puerto Rico was thought to have been the site of daily commutes (Rouse 1992). Even longer sea voyages were regularly taken, either north to the Bahamas or south to the coast of Venezuela, to exchange cotton products and exotic bird feathers. They used large canoes carved out of single tree trunks that were able to hold as many as 150 people (Deagan and Cruxent 2002b). The size, construction, and design of these vessels struck the Europeans as quite remarkable, as did their speed. Las Casas writes of how the European ships on the first voyage were quickly passed by a single man in a canoe spreading the word of the new arrivals to other islands further west.

The political and economic activities of the Taíno were strongly governed by their religious ideas. They believed that all facets of their lives, from the weather to crops to interpersonal relationships, were controlled by spirit beings known as *zemis* (Pané 1999). A zemi could be one of the Taíno's many deities, or it could refer to a physical manifestation of a spirit made of shell, bone, wood, ceramic, or stone. It could also be

part of the decoration on pottery vessels, wood objects, body art, and rock drawings. The zemi was invoked to aid in curing sickness, facilitating childbirth, predicting hurricanes, or strategizing in war. Offerings were periodically made to the zemis, and those that were tangible were kept in special places within the owner's house.

The Taíno seemed eager to receive the small gifts offered by the Europeans when the two groups met. The material objects crafted by the indigenous people stirred the curiosity of the sailors as well. Even the religious beliefs of the Taíno were of some interest to the Europeans, and they were documented by several chroniclers prior to efforts to convert the islanders. Yet none of these things held the same appeal as the small objects worn by a few Taíno that were fashioned from gold found elsewhere on the island or traded for by elites. The motivation of the Europeans was not the study of the New World, but the accrual of riches.

The People Who Met Guacanagarí

Just as the term *Taíno* is used to describe all the different groups of indigenous people living in the Greater Antilles at the time of contact, the word *European* is applied here to the sailors who made the journey to the islands. The backgrounds, religions, and countries of origin of the people on the ships are as different as those found on the various islands. In both cases, they are related to a large degree. Even so, it is important to note that contrary to many descriptions all the colonists were not Spanish and thus cannot be referred to as such. The most prominent example of this is Columbus himself. The admiral's given name was Cristoforo Colombo, and he was born in the province of

Genoa in Italy. He often alludes to his affinity for Genoa, even when it was impolitic in Spain to do so (Fernández-Armesto 1974).

Columbus was not the only non-Spaniard aboard. The ships' manifests for the second voyage are incomplete or entirely missing, but the rosters for the *San Juan* and *Cardera* suggest a number of the founders of La Isabela were Genoese, like Columbus, and Basque (Morison 1942). Others were from Portugal and various states within Italy, as well as many of the regions within Spain that had distinctive cultures of their own. Add to these cultural divisions the fact that quite a number of the sailors came from the same large families (the Niños and Pinzons are but two examples), and the result is a motley band of men partitioned into several camps with distinct ties of loyalty to someone or something other than that of their captain. The factionalism pervaded European society in the Caribbean, starting with the second voyage (Floyd 1973).

The names of women have not been found in the incomplete records. Most historians (e.g., Dor-Ner and Scheller 1991; Morison 1942; Sauer 1966) argue no women sailed to Hispaniola prior to 1498, but the skeleton of a European female has been excavated from within the cemetery at La Isabela (Chiarelli and Luna Calderón 1987). This is a further example of the discrepancy that exists between archaeological evidence and that of the purely documentary sort. Research cannot be based solely on the descriptions found it historical sources.

It is known that more than a few of the crew were criminals and even murderers. Before the first voyage, there was a royal order that pardoned any person who volunteered to serve aboard the ships. Columbus took several of those sailors with him on subsequent expeditions. The types of people who went to sea during this period in

history were typically desperate and from the margins of society: orphans, the very poor, the unemployable, the perpetually inebriated, or those seeking to escape their past in another land (Pérez-Mallaína 1998). The size of the fleet and the number of volunteers meant that there was no effort to screen the colonists for special abilities or personal motivations. There were skilled sailors aboard, and those that could complete important jobs such as barrel making and silver smithing, but no formal training was conducted at the shipyard for the task ahead. Spain in the 1490s was at peace at long last, and soldiers and other young men who would have normally found work expelling the Moors had few other opportunities for employment. Ferdinand Colón describes the random lot that was enrolled for the journey to the West Indies:

> …in a short time [Columbus] had made ready seventeen ships, large and small, well stocked with provisions and carrying all the things and persons needed to settle those lands, including artisans of all kinds, laborers, and peasants to work the land. There came too caballeros, hidalgos, and other men of worth, drawn by the fame of gold and the other wonders of that land. So many offered themselves that it was necessary to restrict the number of those who might go thither, at least until it was known how matters stood in that country and some kind of order had been established there. Even so, the number of people who sailed in the fleet came to fifteen hundred, between gentles and commoners (1992: 108-109).

Most the sailors had dreams of getting rich or elevating their social status, which was possibly more important in Europe at this time. Remaining on land usually meant working an unskilled job for little pay, serving others, or following one's father in whatever occupation that may be. The sea offered an occasion for advancement (Pérez-Mallaína 1998). This was especially the case for the *hidalgos* mentioned above. Hidalgos were minor nobility searching for a way to improve their status. They participated in the *reconquista* of the Iberian Peninsula, where Muslims and Jews were

evicted from their lands, and helped Spain form colonies in places like the Canary Islands. The hidalgos, and many of the others on the ships, wanted to be beneficiates of the practice established after those battles of distributing wealth and resources from newly subjugated areas to the conquerors. The colonists were essentially potential feudal lords seeking land to own, serfs to rule, and titles to win. Unfortunately, the realism of limited gold veins collided with the great expectations held by thousands eager to conquer the New World. Few actually received substantial wealth or achieved status, and this created divisiveness among the colonists.

The Europeans soon also learned they could not expect to become immediately prosperous without resistance. When Columbus left some of his men behind at La Navidad, he referred to the peaceful and friendly nature of the local people. He even told of how the local cacique, Guacanagarí, showed much love for sailors in general and Columbus in particular, going so far as promising "a statue made of him, of pure gold, as large as the Admiral himself" (Las Casas 1989: 301). But on their return to the outpost on the second voyage, the Europeans found the bodies of eight of their sailors in a field near the village of Guacanagarí. La Navidad was in ruins, destroyed by forces marshaled by another cacique. Guacanagarí was said to have fought to protect Columbus's men, but he had to flee after sustaining injuries. Within months of the first contact between Taínos and Europeans, there were grievous actions taken by both sides and the two cultures were internally fractured in terms of their intentions.

Life at Sea

Whether they joined the fleet to avoid turmoil at home or to seek it abroad, all the passengers had to adjust to the routine of a life at sea. The ships were well suited to the travel and supplies were stocked to provide at least six months of food and drink. Still, the conditions could not have been ideal with approximately 90 people on ships with a weather deck measuring slightly more than 20 meters in length (Lyon 1989). There were no quarters for the crew below decks, as the space would have been used for the aforementioned provisions as well as livestock, firewood, gunpowder, and spare materials to repair the ships.

Eating and sleeping would be done amidst the rigging on the deck. A coil of line may serve as a pillow and a barrel could double as both table and chair. Meals were taken whenever possible, and they were made without the benefit of a cook. Cooks were rarely if ever seen on the rosters of 15th and 16th century Spanish ships. In fact, food preparation was considered work for the very lowest class individuals. Telling another sailor his beard smelled of cooking smoke was a tremendously insulting offense, and the comment "go order the cookstove around" was often used to mock the ineffectual commands of a fellow sailor (Pérez-Mallaína 1998). The cultural aversion to culinary activity almost certainly was linked to the sensitive nature of class consciousness. Most of the crew was of subordinate rank and from families not within the nobility. They were aware of their humble status and wished to advance themselves. A connection to lowly mechanical labor like cooking was to be avoided whenever possible. The common distaste for the kitchen foreshadowed the problems of hunger and starvation facing the

colonists in the Caribbean. The lack of women on the ship meant a dearth of cooks on land.

If a sailor wanted a hot dish, he had to make it himself or pay someone else for the service. As fire is a danger aboard a wooden vessel in the rolling sea, the stove used by sailors of the era was a shallow, sand-filled box called a *fogón*. This little contraption, of which there was only one or two on board, served all the passengers. The narrow grill above the flame had to suffice for dozens of pots and pans all heating at the same time. Violence would regularly erupt around the fogón when one sailor shoveled a coal towards their fish and away from their shipmate (Pérez-Mallaína 1998).

All foods consumed on the ships would have been chosen for their ability to last, and the standard menu remained the same over centuries. The sailors mostly ate hardtack baked prior to setting sail and stored in barrels in the driest parts of the ship. Made of unleavened bread, these sea biscuits were cooked twice as a preservative measure, but as a result they had to be soaked for several minutes in water or wine prior to eating. After a few weeks, the hardtack would be laced with weevils and maggots that provided needed protein (Dor-Ner and Scheller 1991). Daily rations also included rice and chickpeas or lentils, probably eaten from a communal wooden bowl using one's fingers as a utensil, and one of a variety of salted meats. Anchovies and sardines were often stored in a brine to stave off deterioration. Pork and beef would be preserved the same way, salted and packed into barrels.

Lines, hooks, and harpoons were used to catch fresh fish and supplement the larder, and some live animals were carried aboard to eat along the way. The most common were chickens, which could also produce eggs. Pigs, too, were slaughtered

during the voyages. All of these animals shared places on deck with their owners, who could keep watch over them and deter thieves when not otherwise occupied. Add to this menagerie all the livestock carried as cargo for use in the New World, together with a host of unwanted passengers like rats, mice, roaches, and lice, and the voyage could rapidly deteriorate into an uncomfortable zoo with sails.

Columbus requested olive oil, vinegar, honey, cheese, almonds, and figs for his sailors on the journey, and it is likely they dined as well as the typical peasant of the era as long as rough seas or a storm did not put out the fire (Morison 1942). Slaking one's thirst, though, proved difficult, especially with the most commonly eaten protein being heavily salted. The only drinks listed in the chronicles of the time were water and wine. The passengers received one liter of each per day, far less than what is recommended in a tropical climate where one can lose a liter of moisture every hour just by sweating. The wine provided calories and probably helped lessen the adversity of life at sea. Some of the water was used to soften the hardtack. None was wasted for personal hygiene. During the second voyage the barrels holding the liquids leaked, which was understandably a cause for alarm. Even in intact casks, the water quickly became stale and took on a bad taste and unpleasant odor. Much of that brought aboard was likely given to the livestock instead of being used for human consumption.

Those aboard Columbus's fleet did not suffer from scurvy because they went less than six weeks between sources of fresh fruits and vegetables. But because the second voyage was delayed in the Lesser Antilles, it took almost 50 days to make landfall at La Navidad. Add to this a month to sail from Spain to the Canary Islands and another almost unfathomable twenty-five days to make the short sail against the wind to La

Isabela (about 160 kilometers), and the total time the passengers spent at sea was over one hundred days. The sailors were tired and sick, the animals were dying, and the provisions were quickly becoming exhausted. They had consumed more than half of the six month supply with which they had left Spain and not one seed had been sowed yet. The passengers were threatening revolt, and Columbus was worried about the fate of the voyage and his grand plans for the colony.

Repartimiento

The immediate problem facing the Europeans at La Isabela was the paucity of food. Hunger and weakness caused by diminished rations led to reportedly widespread illness and even death. Three to four hundred of the settlers fell sick within one week of their landing (Morison 1942), and most of the others followed suit soon after. The colonists could not celebrate mass or apparently stay healthy without their customary and accustomed bread and wine. Yet although the early chroniclers described how well the Old World seeds rapidly sprouted and grew, this was based on their limited experience with a few select vegetables. The wheat withered quickly due to the heat, as did the other Old World grains. The vineyards and olive trees matured very slowly. The bulk of the plants brought from Europe were not adapted to the tropical climate or the different soils of the island. The shortage of crops, and people to work them, took its toll on the colony.

Columbus and the other leaders of the expedition were familiar with the system of *repartimiento*, in place in the Canary Islands where they restocked supplies and across the Iberian Peninsula following the reconquista. They soon implemented this plan in Hispaniola to extract the necessary food, resources, and labor from the Taíno. Through a

repartimiento, the land and people organized by a cacique were allocated to a colonist. In effect, an entire Taíno community was given to a single European. Even though it was never officially condoned, repartimiento was tolerated because of the perilous shortage of food and the lack of labor to mine the small bits of gold. Unlike the later system of *encomienda*, which accomplished the same goals with the additional obligation of Christianizing the subjects, no restrictions bound the person receiving the spoils of the repartimiento. The Taínos were transformed into private property and were supposed to serve at the whim of their European master. After the indigenous people came to realize what the fancy words the colonists were saying actually meant, many of them simply moved out of the area. Those remaining reduced their crops and caused a famine to strike the colony. But this was also a time of high mortality for the Taíno. They were vulnerable to European diseases and many were forced to work against their will. Their social structure was greatly disrupted by the arrival of the colonists and the ensuing movement of Taíno females into some European houses and males into the gold mines and farm fields. The collapse of relations between the two cultures, as well as the populations within each group, was the ultimate effect of this first contact between them. It was in this context of divisiveness and degradation that the colony of La Isabela was created.

CHAPTER 4:

PATTERNS OF CHANGE AND EXCHANGE AS SEEN IN THE PAST

Introduction

What Columbus had discovered in the islands of the Caribbean was not really a New World, although it seems as such to the Europeans. Rather, it was another old world, filled with people who had long been creating cultures as rich and storied as those found on the other side of the Atlantic. The Europeans had trouble fitting these "new" people into their world view, though, and did not give the credit due to these sophisticated farmers and ingenious hunters. Instead of adopting the local practices that efficiently managed the island environment, the colonists tried various unsuccessful measures to directly import their own culinary culture into the new lands. In effect, Columbus did not find a New World, he created one from the linking of two old worlds (Viola 1991).

Traditional anthropological studies have been studying this contact between cultures for some time, but they usually emphasize only the impact the colonial power exerts on the conquered. Cultural exchange is not a one-way street; the flow of ideas, material goods, and organisms runs in both directions (Viola 1991). Although the exchange may be disproportionate at times (pineapples did not transform the landscape of Europe as sugar cane did in the West Indies) or even deadly (syphilis to Europe and small

pox in return), both the local and visiting peoples are transformed through considerable societal changes.

The approach taken in this research on cultural contact is to focus on the influence of the indigenous people and their local environment on the colonial European presence. Specifically, the subsistence patterns of the settlers and their reluctant hosts will provide a glimpse of daily cultural behaviors. Cuisine is a complex web composed of foods available (menu), foods consumed (diet), and adequacy of foods selected (nutrition) (Armelagos 1994). Add to this the methods used to prepare the food and the traditions and taboos governing its consumption, and one is provided a powerful tool with which to examine the behaviors and decision-making processes of people. By gathering resources, producing dishes, and ingesting what is made, food becomes more than just sustenance and transforms into an "object of culture and performance"(Sørenson 2000: 100).

The site of La Isabela becomes a perfect case study for the analysis of interactions because of its time frame and its location. The town is the site of the earliest sustained connection between the two cultures, but it existed only for a brief moment of time. The colonial population had abandoned it for other locations after a period of five years. In addition, the area has a long history of Taíno settlements around La Isabela, and there is even an indigenous cemetery within the town's borders (Deagan and Cruxent 2002a). This chapter will outline the research done in and around this early site, and explain how the modern cultural and physical conditions of the site have limited research into the Taíno influence on the Europeans. The balance of the chapter will then discuss the assorted methodologies that can be used to study cultural contact in terms of biological exchange, especially with regards to subsistence.

History of the La Isabela Area

The town of La Isabela (christened after the Queen and using the Spanish spelling of her name) was officially founded on January 6, 1494 with the celebration of a Catholic Mass. Columbus had put together a massive expedition of 17 ships and up to 1,500 sailors, soldiers, stonemasons, carpenters, and clerics. The expectation was that these colonists would establish a permanent city that would serve as the center of trade on the island. The ships were stocked with plants and animals to serve as food (see Chapter 2). Horses and casks of wine were seen as especially important, although most of the individuals in both categories did not fare well during the three months spent at sea. Only 20 of the horses survived to landfall, and the wine leaked from the barrels from the start.

Columbus was too sick and exhausted to describe the settlement of the town in his own diaries, but his son Ferdinand later outlined the early settlement of La Isabela:

> [H]e proceeded to anchor in front of an Indian village; and having found a plain, with a ravine on one side, that appeared a suitable site for a fortress, he went ashore with all his people, provisions, and equipment… They believed it to be an excellent site for a town because it had a very large harbor, though open to the northwest, and a lovely river a crossbow shot in width, from which water channels could be led to the town, and beyond the river extended a very charming plain, not far from which, according to the Indians, were the mines of Cibao (Colón 1992: 121).

Although the chroniclers, Ferdinand included, crowed about the potential of La Isabela, the site was not as well situated as other possible locations only a few kilometers to either side. The colonists were distraught by the happenings at La Navidad, where Columbus originally planned to settle on his return, and also by the conditions on board the ships. The livestock were dying, provisions were depleted, and morale was low. Columbus, too, was exhausted. He had spent a night on his first voyage in Isabela Bay and knew it

was close to purported gold mines inland. When he finally reached the familiar coastline and saw fresh water, he decided to make it work.

It turns out that La Isabela was more complex than earlier thought. The original town consisted of at least two settlements, a little more than one kilometer apart (Cruxent 1990). The administrative structures, such as Columbus's house, the church, and the customs house, were located up on a cliff over the water's edge, in an area that has now been turned into a park, El Solar de las Americas. The residential, manufacturing, and agricultural parts of the community were on the west bank of the Río Bajabonico in a flood plain adjacent to the bay. This supporting village, where most of the population lived and worked, is now known as Las Coles (see Figure 4.1).

The conditions in the area never really improved as Columbus had hoped. There were epidemics, wide-spread fires, supply shortages, famine, and at least two hurricanes. Further, just as the colonists were struggling against nature, they also suffered from open discouragement and resentment. A rebellion eventually erupted in May 1497, led by the soldier Francisco Roldán. Roldán and nearly one hundred men stole munitions, provisions, horses, and cattle from the town, leading to its demise. By 1498, the attention of the Spanish government turned to the south coast of the island, and La Isabela was deserted.

The Taíno in the area did not fare much better. The Europeans built their town in the vicinity of several indigenous villages, and the people from the two cultures interacted on a daily basis. Archaeological investigations into possible contact period Taíno villages within a few kilometers of La Isabela show a thriving population

Figure 4.1 La Isabela and its environs.

(Caro Alvarez 1973; Ortega 1988; VanderVeen 2005a). By the middle of 1495, however, the chroniclers no longer mention regular Taíno visits as they once did. The indigenous population was likely greatly reduced due to disease, social disruption, forced labor, and overexploitation of food resources caused by European demands (Moya Pons 1992). Size estimations of the population on Hispaniola prior to contact ranges from 60,000 to 14 million, although the most likely number – derived from archaeological assumptions and the accounts of chronicles – is suggested to be between 1,000,000 and 1,500, 000 people (Crosby 2003; Sauer 1966). Within a generation, the count of potential Taíno slaves in one census is 22,726 (Rouse 1992: 158). Whether killed by disease, subjugated into slavery, escaped to another area, or assimilated through marriage, people had all but disappeared from the indigenous villages. It was not a good time to be a Taíno.

After its abandonment, La Isabela was reported to be haunted by the ghosts of Spaniards. Visitors in the area were supposed to have been met by noblemen dressed in late 15th century garb. When hailed, these men lifted their hats in salutation, and their heads came off as well. In the 17th century, any remaining herders or squatters were forcibly evicted from the entire north coast to prevent piracy and smuggling (Palms 1945).

At the time of the 400th anniversary of Columbus's first voyage, Dominicans and Americans worked together to study the area, with little result. Archaeological investigations in the area continued in the early 20th century (Caro Alvarez 1973; Goggin 1968; Palms 1945) and were initiated again in the 1980s by the Museo del Hombre Dominicano (Chiarelli and Luna Calderón 1987; Ortega 1988; Veloz Maggiolo and Ortega 1980). José María Cruxent, from the Universidad Nacional Experimental

Francisco de Miranda of Venezuela, began a long-term extensive research program in 1987 under the auspices of the Dirección Nacional de Parques de la República Dominicana and was joined by a team from University of Florida, led by Kathleen A. Deagan. They produced numerous articles, chapters, and two books on their results (see references in Deagan and Cruxent 2002a, 2002b).

Limitations of Previous Research

Most of the research in and around La Isabela focused on the European presence, as the late precontact and contact-period Taíno culture was assumed to be understood through Spanish documents (Wilson 1990). Moreover, funding for archaeological investigations provided by countries outside the Dominican Republic and from international organizations tends to have a Western culture orientation. This situation is not unique to the Dominican Republic, but it does limit the ability to fully understand the influence of indigenous cultures on colonial powers.

Even the colonial material at La Isabela is incomplete. The very short occupation of the site, only five years, provides a snap shot of colonialism at a specific point in time. Yet the time frame also limits the amount of artifacts in the archaeological record. Most of the buildings were ephemeral houses built with thatch roofs and improvised wood or mud walls. The population was transient, making expeditions inland to the Cibao to search for gold or sailing home for supplies. The first European town in the Americas was more like a large camp site. It was spread wide across the landscape in terms of space but was quite shallow with respect to time and depth of material left behind.

Apparently, in the years between abandonment and the late 19th century, many of the visible stones, clay tiles, or other durable substances used by the colonists in the construction of the larger structures were broken and brought to neighboring towns to build houses (Palms 1945). Some of this was simple recycling of locally available material, but in other cases the removal of large stones was done to commemorate the original settlement in churches or public buildings across the island. Other remains may have been altered during use by 16th and 17th century pirates and slave traders (Wright 1929), as the area was then a remote area with little Spanish governmental control. Many of the remaining rocks used in the walls of administrative structures were sent north to Chicago for the 1893 World's Columbian Exposition (Ober 1893).

Some of the worst destruction of the site occurred during the government of General Rafael Leonidas Trujillo in the mid 20th century. Heavy machinery was used to grade the site at least three times in the course of this period. The surface of La Isabela was to be cleaned up in preparation for the visit of dignitaries, and for the construction of military parade grounds for a show of strength to potential rebels in the area. As a result, buildings and their contents were pushed into sea (Cruxent 1990). In many other places nearly a meter of soil was removed (Deagan and Cruxent 2002b: 83). Any remaining soil was subject to bioturbation by modern animals, especially the land crabs that are ubiquitous in the low areas both on shore and further inland. These invertebrates are known to cause substantial disturbance (Keegan, et al. 2003) and have been noted in the area by the Indiana University research team, particularly at Las Coles. The result of the vandalism, looting, and development that transpired at La Isabela compromises the 15th century provenience of the site. There is effectively no intact and undisturbed

stratigraphy and few contexts that include solely colonial material (Deagan and Cruxent 2002a). Still, a plethora of ceramic and metal artifacts were excavated by the various projects, and others remain *in situ* at Las Coles and on the fringes of La Isabela itself.

The evidence of subsistence patterns, on the other hand, is scarce. Deagan and Cruxent conclude that "no reliable interpretation of the Spanish diet at La Isabela could be derived from the archaeological faunal assemblage" (2002a: 144), and the plant remains are even less well represented. A number of explanations could be offered for this discrepancy: the colonists were indeed starving, they did eat well but the food was prepared by the Taíno and brought to the town potluck-style, they ate primarily fish which was filleted on shore and the meat transported to the houses, a rigorous system of composting took place to help the nascent agricultural fields, or the dogs and pigs scavenged the leftovers. All of these events could have happened, and each of these hypotheses explains only a portion of the circumstances. Regardless of the details, the fact remains that little direct faunal or floral evidence has survived to illuminate either the diet of the Europeans or the Taíno they met.

There are a number of techniques that exist which can identify the culinary habits of people based upon data other than that of plant and animal remains. As developments are made in increasing the sensitivity of instruments and protocols are revised to better fit the biochemical methods with archaeological questions, the accuracy of analysis improves rapidly. Approaches in studying archaeological chemistry include infrared spectroscopy (Badler, et al. 1990), isotopic analysis (Tripp and Hedges 2004), nuclear magnetic resonance spectroscopy (Sherriff, et al. 1975), and thin-layer chromatography (Kharbade and Joshi 1995). One of the most widely used methods is that of stable-

isotope analysis, which measures the flow of dietary components through the food chain by comparing the ratio of particular elements present in a sample of organic tissue. In most cases, the tissue of interest is from human bone found in burials. Several studies of this sort have been done in the tropical regions of North and Central America (e.g., Keegan and DeNiro 1988; Tuross, et al. 1994; Tykot, et al. 1996; White, et al. 2001).

Of course when the bones of any person are destroyed by scientists, as is required in stable-isotope analysis, numerous ethical considerations arise. Is it appropriate to treat the dead in this way? Does permission need to be granted from the purported descendents? Can direct descendents be found, and what happens if they are not? If there is any disagreement among the parties involved, whose decisions prevail? Are the data obtained worth the loss of the bone or the trouble caused by any disagreement and dispute? The use of human bones in archaeological investigations comes with substantial social and political dilemmas that must be confronted by those with a stake in the research.

Stable-isotope analysis can also be done on charred residue from cooking vessels. Unfortunately, the presence of enough of such material is rare in the archaeological record, and virtually nonexistent if the artifacts were cleaned and stored as is the usual method after excavation.

Potential of Present Project

Fragments from ceramic cooking vessels and serving dishes are commonly found littering indigenous sites in the area around La Isabela, and comparable types of materials from colonial contexts were heavily collected by researchers investigating the town itself.

Residues absorbed into these sherds are clearly associated with the consumption of food, to the same degree as substances charred on to their surfaces, and the destruction of such pottery is legal and more ethically acceptable than the use of human bones. The everyday cooking pot or dinner plate, in spite of how it may have been collected or processed by archaeologists, is an ideal candidate for aiding in the reconstruction of dietary practices of those who used it.

When foods that have some liquid component are stored or processed in unglazed ceramic vessels, the organic material permeates the porous surfaces. This is especially true when the foods are cooked, as the heat allows the ingredients to be more easily absorbed (Charters, et al. 1993; Evershed, Stott, et al. 1995; Heron and Evershed 1993). As long as the vessel is used, it continues to be infused with the organic material from its contents. Polar compounds, such as lipids, have a slight electromagnetic charge that forms a weak bond with particles within the clay matrix of the pot. This bond is not usually broken by soap or water, although strong organic solvents will extract the compounds.

At the end of its use life, the assorted compounds accumulated within the ceramic walls begin to be altered and broken down. This occurs more rapidly for water-soluble components, such as carbohydrates and proteins. The hydrophobic lipids are resistant to leaching and remain at various level of intensity for hundreds or even thousands of years (Bethell, et al. 1994; Evershed 1993b; Skibo 1992). Lipid residues are also provided protection by the size of the pores within the ceramic wall. Microorganisms seeking to use the compounds tend not to be able to fit inside the pores, and the compounds are therefore protected from microbial attack.

Add to this the fact that lipids are present at high levels in virtually all types of food and most suffer only minimal degradation from moderate cooking temperatures (Rottländer 1990), and the above characteristics of preservation and stability make lipid analysis an ideal candidate for the reconstruction of vessel contents. For over 30 years, researchers have used various detection techniques to recover and identify lipid residues absorbed into pots and dishes – with differing degrees of success. The increase in availability and sensitivity of gas chromatographs and mass spectrometers instruments, in conjunction with experiments designed to refine extraction protocol and model behavior of organic material over time (e.g., Dudd, et al. 1998; Mottram, et al. 1999; Regert, et al. 1998) has improved the ability to characterize residues.

Much of the past research has been used to identify a particular genus or species of food from the preserved residue (see Table 4.1). In these instances, the investigation began with a food already in mind. The clues may be based on ethnographic information regarding the traditional use of a vessel type (Skibo 1992), the vessel's characteristic form (Evershed, et al. 2003), or even the depiction of a food directly on the vessel itself (Hurst, et al. 1989). The association between the presence of unique lipids and a certain type of food creates a particular signature, or "biomarker," for that food. Whenever a biomarker is recovered from among the preserved residue, one can reasonably assume the substance with which it is linked was once contained within that vessel. While studies of this sort are of great interest, their specificity provides little guidance in reconstructing the contents found in the majority of archaeological sherds.

Other experiments in residue analysis have involved the comparison of organic material as found in small number of modern samples with that in archaeological sherds

Table 4.1 Specific and general sources of biomarkers used in residue analysis.

Identified Substance or Category	*Selected Reference**
Adhesives	(Regert, et al. 2003)
Animal fats	(Evershed, et al. 1997)
Aquatic species fat	(Hansel, et al. 2004)
Beaver fat	(Malainey, et al. 1999b)
Beeswax	(Regert, et al. 2001)
Bovine fat	(Kimpe, et al. 2002)
Cabbage leaf wax	(Charters, et al. 1997)
Cocoa	(Hurst, et al. 1989)
Copal	(Stacey, et al. 2006)
Kava	(Hocart, et al. 1993)
Lamp oil	(Copley, Bland, et al. 2005)
Maize	(Reber, et al. 2004)
Milk	(Dudd and Evershed 1998)
Moose fat	(Deal and Silk 1988)
Mustard seed oil	(Colombini, et al. 2005)
Nicotine	(Rafferty 2002)
Olive oil	(Condamin, et al. 1976)
Piñon	(Eerkens 2005)
Pitch	(Robinson, et al. 1987)
Plant oils	(Coyston 2002)
Porcine fat	(Dudd, et al. 1999)
Resins	(Shackley 1982)
Seal fat	(Patrick, et al. 1985)
Squash seed oil	(Coyston 2002)
Waxes	(Charters, et al. 1995)
Whale oil	(Morgan, et al. 1983)

*The studies provided here are not the exclusive references for each food type but were chosen as being representative of the identification process. Refer to the works cited in the above references for additional information.

(Coyston 2002; Malainey 1997; Marchbanks 1989; Reber 2001). The researchers collected samples of plants and animals native to the areas from which the sherds were recovered and therefore expected to be processed by the people using the pottery. The samples were then cooked in the laboratory and the resulting lipid extract was run on a gas chromatograph to develop an analytical reference for that particular food or food combination. In some instances, the researchers took the further step of forcing lipid degradation, in which the sample was heated continually for a period of time to replicate sherds recovered from ancient deposits (e.g., Craig, et al. 2004; Dudd, et al. 1998; Raven, et al. 1997).

The advantage of gas chromatography-mass spectrometry analysis of absorbed residue is that is can also be used to characterize a broad class of foods, such as the processing of plants versus meats, or narrower identification like terrestrial versus aquatic animal. In this way, patterns of unexpected subsistence can be observed. Models of culinary behavior by people in the past may be incomplete if the analysis is limited to the search for a specific biomarker or comparisons to a set of known food types. Most substances of interest have not been examined in this way. Many foods eaten hundreds of years ago are no longer widely found or used in the present and, as a consequence, no library exists of their lipid composition. Moreover, several species have been hybridized, and their signatures have changed as a result. Other chemical modifications take place during processing which may alter the signature of the compounds within the food.

The decision was made in this study to take a wide and inclusive perspective with regards to the lipids analyzed, as absorbed residue research has not previously been done in the geographic area of the Caribbean. As noted above, the evidence of floral and

faunal remains are at best limited and often completely absent in the archaeological record of colonial sites in the area. Further, while there are historic accounts of the foods included in the diet of the European settlers, the subsistence patterns of the Taíno are less well-known. Any identification made by the chroniclers was done with an imperfect knowledge of indigenous behavior and was usually described in terms of analogies to Old World species. Examining the various classes of foods used by both cultures without confining the analysis to a restricted set of species allows for a more practical and complete reconstruction of their diets. After the comprehensive suite of food sources and production techniques is better established, more targeted reconstructions of culinary decisions can be attempted, although this would constitute a very lengthy and expensive process.

In addition to identification of foods contained within vessels, residue analysis also may aid an archaeologist in interpreting how the vessel was originally used by its owner. Lipids do not always accrue at a uniform rate throughout the body of the vessel. Instead, they may be concentrated in a particular body area, based on how the food was cooked. Substances that are boiled or stewed leave residue at the neck or rim, because of the organic matter that floats to the surface during heating, while the lower portion of the vessel has relatively lower densities due to thermal degradation (Evershed, Charters, et al. 1995). Roasted or fried foods show the opposite tendencies, with higher levels near the base where the food is in contact with the vessel surface (Charters, et al. 1993). Residues that are evenly distributed throughout the ceramic matrix, from top to bottom, suggest that the vessel was either treated after firing with a fat or wax to decrease the porosity or

may have been used in the storage of more viscous foodstuffs like oil. Ceramic dishes used only for serving food show evidence of residue, but at a relatively lower rate.

Different use patterns over the life of the vessel would leave distinctive traces to indicate which materials it may have held and how they were processed. Unfortunately, these patterns may overlap in such a way that differentiation of sources is difficult. The sealing of a vessel's walls with a non-food fat could mask the identification of the lipids cooked within the vessel, or the residue left behind from both episodes could coincidentally match the fatty acid pattern expected to be left by a third substance. When several varieties of plants or animals are cooked within a pot, the recognition of separate species is challenging, yet possible if a unique lipid or lipid ratio is present (Skibo 1992). A thorough and careful analysis by a scientist experienced with characterizing lipids may reduce the likelihood of an erroneous identification; the conclusions are limited by available knowledge. By combining lipid analysis with the expected use patterns of the vessel and its archaeological context, however, the rate of inaccuracy can be further lessened.

As mentioned above, lipids are the primary organic residue analyzed in dietary reconstruction, and as such a brief description is in order. For a full explanation of the characteristics of lipids and a systematic report on the various procedures of separation and identification, refer to Christie (1973; 1989; 2006). Lipids are a class of substances which have low or variable solubility in water but are soluble in organic solvents. They occur in all organisms, where they serve many metabolic and structural functions. Lipids may be found in the form of fatty acids, fatty alcohols, acylglycerols, sterols, and waxes.

Most chemical analyses for archaeological purposes have been conducted on fatty acids. These exist in nature as free fatty acids, triacylglycerols, and wax esters and represent the vast majority of all lipids in plant and animal species (Malainey 1997). Fatty acids may be saturated, in that each carbon in the chain is connected to its neighbor by a single bond (see Figure 4.2a). Saturated fatty acids are relatively stable and solid at room temperature. Mammal fat is predominately saturated, whereas plant and fish oils are primarily unsaturated fatty acids, although plants themselves contain saturated fatty acids. Common unsaturated fats are liquid at room temperature and contain at least one double bond between carbon atoms (see Figure 4.2b). Those fats which have more than one double bond, known as polyunsaturated, oxidize easily and are markedly less stable than unsaturated fatty acids.

Wax esters are long chains of fatty acids chemically linked to long-chain alcohols (see Figure 4.2c). They have a variety of uses in the natural world. The protective coatings on plant leaves and fruit are made in part from wax esters. They are also found in animal and insect secretions. Some fish use wax esters in their swim bladders, and zooplankton use them for energy reserves. The natural breakdown product of wax esters derived from the protective coatings of leafy flora are long-chain alcohols, a biomarker for some plant materials (see Figure 4.2d).

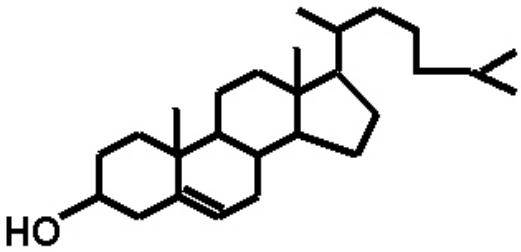
One of the most recognized lipids is cholesterol, a biomarker found in the tissue of animals. Cholesterol is the principal sterol, which are multi-ringed hydrocarbons (see Figure 4.2e). Sterols are produced by all eukaryotic organisms, and plants produce campesterol, sitosterol, and stigmasterol which also serve as biomarkers for floral material. Other sterols are produced by fungi and algae. Terpenoids are similar to sterols

a) Saturated fatty acid - hexadecanoic (palmitic) acid

b) Unsaturated fatty acid - octadecenoic (oleic) acid

c) Wax ester - dodecyl hexadecanoate (lauryl palmitate)

d) Fatty alcohol - hexadecyl (cetyl) alcohol



e) Sterol - cholesterol

Figure 4.2 Chemical structures of lipids.

The compounds are shown in abbreviated line formulae, in which each carbon atom is indicated by an end or bend of a line. Hydrogen atoms are not shown but are assumed to be present in known amounts due to the consideration of each carbon's valence. Double bonds are shown by double lines.

in that they are also multi-ringed and found in a great diversity of plants and animals. The primary sources for terpenoids in absorbed residues, though, are tree resins. For some of these, their very species of origin can be determined (Eerkens 2005; Evans and Heron 1993).

All lipids decay over time and in the presence of oxygen. While a particular combination of fatty acids and their proportions may be distinctive in fresh foods, the lipid content becomes more alike and less distinguishing as a number of processes lead to their decomposition, increasing the difficulty of positive identification (Heron and Evershed 1993). The degradation of fatty acids begins at the moment of food processing, whether it involves killing a fish or cutting into a manioc. It continues during cooking or storage and through the subsequent discard and burial of the vessel into which the lipid had been absorbed.

Oxidation occurs when foods are exposed to oxygen, and this process has the most deleterious effect on the ultimate composition of the fatty acids within ceramics (Evershed, et al. 1992; Malainey 1997). The reaction begins when an unsaturated lipid becomes a free radical after losing a hydrogen atom. This free radical can combine with oxygen, and the resulting compound then frees another atom of hydrogen. A chain reaction is set in motion, the result of which is a reduced number of unsaturated fatty acids present in the residue.

Hydrolysis is another process through which fatty acids are lost. Heat and enzyme initiators promote the decomposition of lipid compounds by reaction with water. When this occurs, fatty acids are released from the triacylglycerols of storage fat

(Evershed, et al. 1992). Heat or dehydration can also cause thermal degradation of lipids, creating many of the same products and results as oxidation.

Other processes, such as microbial degradation and adipocere formation, can lead to the decomposition of lipids, changing the original components of a food to something quite different over time. Yet despite these challenges, researchers have continued to apply fatty acid analysis to the reconstruction of people's diets in the past. Several studies have been done that attempt to recreate the conditions faced over time by residues absorbed into archaeological sherds. Patrick and colleagues (1985) boiled tissue from seals and then heated the residue for nearly 90 days in an oven. They found the ratio of oleic ($C_{18:1}$, ω-9) to vaccenic ($C_{18:1}$, ω-7) acids did not change significantly between fresh and degraded samples. Marchbanks (1989) used a different ratio of fatty acids (linoleic [$C_{18:2}$] and linolenic [$C_{18:3}$] acids to those plus lauric [$C_{12:0}$] and myristic [$C_{14:0}$] acids) but found similar results in terms of comparative results between modern and archaeological samples. The key was to use one set of fatty acids that were known to occur in large amounts in animal tissue and another set found in high levels within plants.

A sufficient number of other studies (Deal, et al. 1991; Evershed, et al. 1992; Malainey, et al. 1999a; Morgan, et al. 1983; Skibo 1992) have corroborated the fact that, as long as decomposition factors are considered, fatty acid analysis can provide a fairly accurate interpretation of culinary practices. Analytical techniques must not rely on too few lipids for identification, nor should methods focus only on specific compounds. Due to the variable preservation of sherds, differences in the construction of vessels, and dissimilarities between species used for food, not all methods created for identification in one area or time may be applicable in every situation. All the same, the selection of

appropriate classification criteria can be useful in classifying a large number of samples in a short amount of time.

The approach taken in this study is not to characterize all the individual foods that were once eaten by specific individuals in the past. Raw fruits and vegetables, roasted meats, and other foods not processed within ceramic vessels are impossible to recognize through this method. Pots may be employed for more than one purpose over their use lives, and some may have served more than one household or generation. Instead, this research compares the general classes of food selected by particular groups of people as appropriate for consumption. A large number of lipids of various types (see Table 4.2) are examined to better reconstruct the subsistence patterns of Taíno and Europeans living in the same area at approximately the same period in time. The ultimate goal is to investigate why two very distinct cultures living in similar conditions chose one food rather than another in the preparation of their daily meals.

Table 4.2 Common lipids targeted in the analysis of organic residues.

Shorthand Designation	*Common Name*	*Systematic Name*	*Typical Source**
$C_{8:0}$	Caprylic	octanoic	coconut & palm nut oil; some butterfat
$C_{10:0}$	Capric	decanoic	coconut & palm nut oil; some butterfat
$C_{11:0}$	Hendecanoic	undecanoic	some butterfat, human hair
$C_{12:0}$	Lauric	dodecanoic	Lauraceae/Palmae seed oils
$C_{14:0}$	Myristic	tetradecanoic	Myristiceae seed oils; low in most species
$C_{14:1}$	Myristoleic	tetradecenoic	low in bacteria and plant oils
$C_{15:0}$	Pentadecylic	pentadecanoic	bacteria, human skin oil, fish, and plants
$C_{16:0}$	Palmitic	hexadecanoic	virtually all animal fats and plant oils
$C_{16:1}$	Palmitoleic	hexadecenoic	animal fats (esp. cold-blooded); some plants
$C_{17:0}$	Margaric	heptadecanoic	human skin, fish oils and bacterial lipids
$C_{17:1}$	Margaroleic	heptadecenoic	squash seeds; some ruminant fats
$C_{18:0}$	Stearic	octadecanoic	virtually all fats and oils; high in ruminants
$C_{18:1}$	Oleic	octadecenoic	virtually all fats and oils; low in mollusks
$C_{18:2}$	Linoleic	octadecadienoic	plant oils and herbivore fats
$C_{18:3}$	Linolenic	octadecatrienoic	plant oils; low in herbivore fats
$C_{19:0}$	Nonadecylic	nonadecanoic	bacteria, some in human skin oil
$C_{20:0}$	Arachidic	eicosanoic	seed and fish oils; low in most animals
$C_{20:1}$	Gadoleic	eicosenoic	aquatic animal fats
$C_{20:4}$	Arachidonic	eicosatetraenoic	animal organ fats (liver, brain tissue)
$C_{22:0}$	Behenic	docosanoic	mustard, peanut, rapeseed, fish oils
$C_{22:1}$	Erucic	docosenoic	Cruciferae seed oils, fish oils
$C_{24:0}$	Lignoceric	tetracosanoic	low levels in some land plants
$C_{24:1}$	Selacholeic	tetracosenoic	low levels in some aquatic species
$C_{26:0}$	Cerotic	hexacosanoic	wool fat; plant and insect waxes
$C_{28:0}$	Montanic	octacosanoic	plant, insect waxes
$C_{30:0}$	Melissic	triacontanoic	insect waxes
$C_{32:0}$	Lacceroic	dotriacontanoic	insect wax, “sticklac” wax
OH C_{14}	Myristyl	tetradecanol	waxes associated with pine pollen
OH C_{16}	Cetyl	hexadecanol	plant cuticle wax, beeswax
OH C_{18}	Stearyl	octadecanol	insect waxes
OH C_{20}	Arachidyl	eicosanol	insect waxes, especially bees
OH C_{22}	Behenyl	docosanol	algae wax
OH C_{24}	Lignoceryl	tetracosanol	some plant waxes
OH C_{26}	Ceryl	hexacosanol	barley or oat wax
OH C_{28}	Montanyl	octacosanol	wheat wax
OH C_{30}	Myricyl/Melissyl	triacontanol	sugar cane wax, plant cuticle wax, beeswax
OH C_{32}	Lacceryl	dotriacontanol	maize and C4 grass wax
OH C_{34}	Geddyl	tetratriacontanol	some plant waxes
		cholesterol	animal fats
		dehydroabietic acid	plant (pine) resin
		phthalates	plastic bags and sheeting, nail polish
		squalene	shark/ray fat, olive oil, human skin oils
		stigmasterol	plant oils

*Based in part on Christie (1973) and Deal and colleagues (1991). The “typical” sources are the most likely or common, although other origins are possible.

CHAPTER 5:

RECONSTRUCTING SUBSISTENCE PATTERNS

Introduction

This chapter outlines the methodology used in the current research. The first section outlines the criteria used in selecting the sherds and soils. A description of the archaeological sites from which the sherds were taken is next, followed by explanation of the extraction protocol and the specific parameters of the instruments used in analysis. The final section of the chapter illustrates the ways the absorbed organic residues were identified.

There are a number of methods used to extract organic material from pottery (Charters, et al. 1995; Eerkens 2005; Evershed, et al. 1990; Kimpe, et al. 2004), all with slight differences to target specific needs. The protocol primarily used in this study was modified from those in the literature in order to best fit the instrumentation selected to aid in lipid analysis. Until this time, no other research had been done on absorbed organic residues from pottery used in the Caribbean Basin. It was not known before the extraction and analysis of these sherds which specific lipids would be encountered or which biomarkers would effectively discriminate between different classes of foods. Therefore, the primary goals of this study were to test the feasibility of successful extraction from sherds deposited in tropical environments and to make a comparison of

lipid ratios between vessels associated with the different cultures found in that environment. The most efficient way to achieve these goals was to employ gas chromatography-mass spectrometry (GC-MS) as the analytical method. This technique is especially effective at separating and identifying a large variety of lipids. It is also used by other archaeologists and the machines are relatively common in other laboratories, both of which make comparison of data and replication of studies possible.

Sampling Criteria

In an effort to examine the breadth of resource exploitation as evidenced by food production, the sherds used in this study come from a total of eight indigenous village sites and two European settlements across three distinct regions within the Dominican Republic. All of the sites are within three kilometers of the coast, and permission to remove artifacts from the Dominican Republic was granted by the Secretaría de Estado de Cultura and the Museo del Hombre Dominicano. Most of the sites are tightly clustered around the La Isabela area in the northwestern corner of the country, controlling for environment in the comparison of cuisines. Material used by indigenous peoples at two sites in a northeastern province and one site in a southeastern province was also analyzed. Aside from adding to the geographical and ecological scope of the research, these sherds also provide further diversity due to the differences in excavation techniques used and conditions of subsequent storage. For example, those samples from Los Hoyos de Molina were recovered from a submerged context within a freshwater spring. A substantial length of time under water may have an influence on the preservation of organic material within the ceramic matrix.

Only the sherds from four sites (Edilio Cruz, Loma de Leonardo, El Tamarindo and El Perenal) were collected specifically for this project. The sherds from El Tamarindo were wrapped, without being washed, in paper and placed in separate bags immediately after excavation. Those from Edilio Cruz, Loma de Leonardo, and El Perenal were collected from the surface and protected by aluminum foil until analysis. The remaining sherds were taken from excavations that had occurred between one year and, in the case of those from La Isabela, nearly twenty years ago. This material had been handled several times prior to residue extraction. Most of the sherds had been washed with water, a few were marked with catalogue numbers, and many were stored in plastic bags. Refer to the listing of samples in Appendix A for complete contextual information.

The foremost consideration with regards to the specific sherds selected from each site was the likelihood of successful residue extraction. The 75 sherds in this study are all from vessels interpreted as being related to food production. Most of the sherds, although small, may still be recognized by their shape as parts of vessels likely to have been used for storing, cooking, or serving food. The typical vessel form represented is a bowl (n=33) or jar (n=15), although other domestic shapes such as indigenous buréns (n=4) and a European dish, *plato* or plate, and *cantimplora* or a canteen-like bottle were sampled as well.

Most archaeology of pre-Columbian sites in the Caribbean does not result in the positive identification of particular house rooms or food warehouses. Therefore, material from an area recognized as a kitchen due to a recognizable cooking hearth or concentrations of domestic residue is nearly nonexistent. While preservation of

residential structures is rare, middens abound. Small, mostly nondescript fragments of ceramic vessels purposefully thrown away by their original users are common in the archaeological record, and it is from these pieces that the samples were selected. These sherds were for the most part undecorated (n=47, 63 percent), and some (n=20, 25 percent) were so general in shape it was impossible to determine their form. These broken vessel fragments may no longer have had use for a Taíno or European cook, and the morphological data they hold for archaeologists is extremely limited, but they can still be employed for the purposes of this research.

It was a deliberate choice to use a large number of sherds from curated contexts and without diagnostic decorations in this analysis. Collections of this sort, which are common and often available for use, may have been untouched for years. It is to the benefit of archaeology that absorbed residue analysis can be utilized on material already excavated since sites are ever dwindling due to the expansion of commercial and residential development across the world. Gathering more information from the same number of artifacts is a methodological approach that is both efficient and ethical.

Description of Sites

El Tamarindo [laboratory identifier TAM]

Most samples in this analysis come from the excavation conducted by the Bahía Isabela Archaeological Project at El Tamarindo, a site in the northwestern corner of the Dominican Republic (see Figure 5.1). It is situated on a ridge overlooking the Río Bajabonico as it empties into the Atlantic Ocean in Isabela Bay. The site is densely

Figure 5.1 Archaeological sites in northwest Dominican Republic.

wooded at present but easily accessible via paths used by local people and livestock as a shortcut between destinations. Features of the site include an exposed clay source, more than one human burial previously disturbed by pot hunters, and a relatively heavy scatter of sherds and shells visible on the surface.

Twenty-three indigenous sherds were selected during the course of a larger archaeological excavation conducted by the Bahía Isabela Archaeological Project during the summer of 2005. The vessels were primarily bowls (n=10). The remainder were buréns (n=2), jars (n=2) and undeterminable (n=9) forms. From these artifacts, two soil samples and two charcoal samples were recovered. During the excavation, both Chican and Meillacan sherds were identified from the 68.4 kilograms of pre-contact ceramic material; post-contact artifacts were also encountered but all were determined to be from the 20th century or later (VanderVeen 2005b). The sample in this analysis consists of seven Chican, four Meillacan, one incised, and 11 undecorated sherds.

El Perenal [PER]

Related to El Tamarindo is the site of El Perenal. The ceramic artifacts found at El Perenal suggest the site's residents were Macoríx, the makers of Meillacan Ostionoid pottery (Veloz Maggiolo in Deagan and Cruxent 2002a). Yet the investigations by the Bahía Isabela Archaeological Project have recovered both Meillacan and Chican Ostionoid at both sites (VanderVeen 2005a, 2005b). With the center of El Perenal less than one-half kilometer to the east of El Tamarindo (see Figure 5.1), the two sites may instead be part of a large village residence. Additionally, previous excavations have shown that both sites were occupied from circa A.D. 1300 to after contact (Ortega 1988).

Because the site of El Tamarindo was not investigated for this project until a year after similar work was done at El Perenal, the sites have different laboratory identifiers. A total of six sherds (one Chican, one Meillacan, and 4 undecorated) were collected from the surface for analysis. Of this sample, three were from bowls, two from jars, and one from an unknown form. One sample of the soil from the site was also collected.

La Isabela [ISA]

The other site contributing a large portion of sherds to this study (n=22) is that of La Isabela, the first European-style town in the Americas. The site is directly on Isabela Bay, about five meters above the water on a low cliff. El Tamarindo is 1.7 kilometers to the northwest (see Figure 5.1). Several archaeological excavations and other disturbances are obvious at the site. The material used in this analysis comes from the Solar de las Américas museum at the site, a repository for some of the artifacts collected during excavations in the 1980s and 1990s conducted by institutions in the Dominican Republic, Spain, United States, and Venezuela (Deagan and Cruxent 2002a, 2002b).

Of the sherds from La Isabela analyzed in this project, 19 were of European origin and presumably date to before 1498 when the colony was abandoned. The forms of the vessels varied greatly: six each of bowls and jars, one each of cantimplora, dish, and plato, and four of unknown morphology. Eight of these sherds were decorated with some form of incised line or triangular ridge, but none were glazed. Another three undecorated indigenous sherds – a burén, a bowl, and an undetermined vessel form – were also selected. These artifacts are thought to have been used prior to contact (Deagan and Cruxent 2002a).

Las Coles [ISA]

A part of the Solar de las Américas museum collection is from material collected at the nearby site of Las Coles. Since the documentation regarding the field sample numbering system used by the excavators was not found until after the samples were collected, this site shares the same identifier as La Isabela.

Now a cultivated field just south of Río Bajabonico and 2.1 kilometers west-southwest of El Tamarindo (see Figure 5.1), Las Coles was likely a non-fortified agricultural settlement founded by Columbus at the same time as La Isabela (Deagan and Cruxent 2002a). Whereas La Isabela is elevated above the sea, making it defensible and offering a view of incoming ships, Las Coles is in a floodplain. The advantages of this satellite site are easier access to fresh water from the nearby river and better soil in which to grow crops and pasture livestock. The colonial period European sherds from this site included in this analysis are two decorated jar necks and a fragment of an undecorated, undetermined vessel form.

Loma de Leonardo [LEO]

About two kilometers northeast of El Tamarindo is the site of Loma de Leonardo (see Figure 5.1). It is on a similar ridge and also overlooks the bay. There are a large number of looting pits visible, although all are on the sloping sides of the site and not in the middle of the presumed occupation (VanderVeen 2005a). Two large sherds, one a Meillacan bowl and the other an undecorated jar, were collected from the surface of the site. Soil was recovered from each sherd and another soil sample was taken directly from the site.

El Sitio de Edilio Cruz [ECZ]

Located in an open pasture 17.5 kilometers southwest of El Tamarindo is the site of Edilio Cruz (see Figure 5.1). A sherd of possible European origin was found on the surface of the site, as well as indigenous ceramic artifacts (VanderVeen 2005a). Four sherds were analyzed, one Meillacan and three undecorated. They were from jars (n=2), a bowl, and an unknown vessel form. Two soil samples were taken from the sherds, and an additional soils sample was collected from the site.

Punta Rucia [ES]

A small sample from a cache of ceramic and human skeletal material collected by an informant to the Bahía Isabela Archaeological Project was used in this project because of its association with potential colonial European artifacts, including a clay pipe bowl and a possible colonial-period sherd (Conrad 2004). The collection was recovered from a single site near Punta Rucia, about 15 kilometers west of El Tamarindo (see Figure 5.1). The skeletal material was from a male aged 18-24 years and a year-old infant. The ceramics used in this analysis include two Chican, four Meillacan, and one undecorated sherds, all of which were from bowls. Two soil samples taken from the ceramic fragments were also investigated.

Cangrejera Oeste [CO]

During the summer of 2002, a research team from Indiana University conducted a small investigation of an archaeological site in the southeast of the Dominican Republic (VanderVeen and Conrad 2002). Working in conjunction with personnel from El Museo

del Hombre Dominicano, the archaeologists surveyed the site and excavated a number of test pits within a previously disturbed area to ascertain the extent of prehistoric occupation. This site, known as La Rosa de Bayahibe or Cangrejera Oeste, is 290 kilometers southeast of El Tamarindo, on the shore of the Caribbean Sea (see Figure 5.2). The area is between resort properties, and is a sandy expanse covered with few trees at present. Despite the construction and grading in the area, it did yield Chican pottery, shell and stone tools, and human remains. The pronounced disturbance of the site, and the condition of the artifacts it still contains, did not suggest that further archaeological investigations were needed, however the material collected during the excavation has been used in additional analyses (Conrad, et al. 2005). For this study, a Chican bowl, an undecorated burén, and an undecorated vessel of unknown shape were used. From these, one soil sample was also collected.

Punta Macao [PM]

Almost 300 kilometers from El Tamarindo, also on the Atlantic coast but in the northeast of the country, is the site of Punta Macao (see Figure 5.2). This site was excavated in 2003 and 2004 by personnel from the Museo del Hombre Dominicano and Museo Faro a Colón. The investigators provided one sherd from a Chicoid bowl and one from an undecorated bowl for absorbed residue analysis. From these, one soil sample was recovered. Nothing is known about the provenience of the sherds or the methods used in processing the artifacts subsequent to their excavation.

Figure 5.2 Archaeological sites in eastern Dominican Republic.

The site of Hoyos de Molina is in close proximity to Punta Macao. Shown for comparison is the site of El Tamarindo.

Los Hoyos de Molina [HM]

Hoyos de Molina is a cavern filled with fresh water near Punta Macao. The same investigators responsible for the Punta Macao excavations made available one undecorated bowl, one undecorated jar, and one undecorated vessel of undetermined form. These three sherds had been submerged for scores, if not hundreds, of years.

Artifact Documentation

Owing to the fact that the primary protocol used to extract organic compounds from the body of the ceramic sherds results in their destruction, extensive documentary records were kept regarding the material. Each sherd was sketched, photographed, weighed, and prominent attributes (vessel form, vessel area, color, temper, decoration, and the like) were noted. These data are available in Appendix A to this document. Further, since a portion of the samples were initially collected by excavators unaffiliated with the Bahía Isabela Archaeological Project, the original unique identifiers or field sample numbers for those sherds were also registered. In this way, the necessary context may be reconstructed if needed.

Extraction Procedure

Once the samples were selected and documented, most were cleaned using a stainless steel cut-off bit and a rotary drill within a laboratory fume hood (a novel, nondestructive protocol is discussed below). Approximately one millimeter of all exposed surfaces, including edges and within incised lines, was removed. This was to ensure that specimen labels, dirt, and other impurities would not contaminate the target

residue within the sherd (Heron, et al. 1991). The drill bit was rinsed with a dichloromethane/methanol (2:1 v/v) solution after each sherd was cleaned so as to prevent potential cross-contamination of samples.

Next, the sherds were weighed on an electronic balance. The samples were between two and 30 grams and averaged 13.30 grams, with one exception. An entire fragment of burén (CO 01) weighing 44.2 grams was used because the top surface of the sherd, where food would have been placed, was too difficult to remove from the bottom. Typically, sherds larger than 15 grams were scored and broken to meet this target size.

After being cleaned and weighed, the samples were ground into a fine powder using either a degreased agate or iron mortar and pestle. The sherds used by the colonists were fired harder than the indigenous ceramics and were very difficult to crush effectively with the smaller agate pestle. Instead, a larger iron apparatus was used. Both sets of mortars and pestles had never seen oils, and the dichloromethane/methanol solution was used as a rinse after each powdering episode.

The samples were again weighed to determine the amount of solvent used with each and were then typically placed in a clean Teflon centrifuge tube with a Teflon-lined lid. A 40 milliliter glass centrifuge tube with Teflon-lined cap was used with samples weighing less than five grams or with some chemical controls. An equal volume (to sherd weight) of the dichloromethane/methanol solution was added to the sample and the solvent and powder were gently agitated to mix.

The entire process, from cleaning to mixing, took place within one hour so as to limit the risk of laboratory contamination of samples and oxidation. In order to accomplish this, batches of only four to six samples were processed at one time. For the

same reason, all surfaces and objects with which the samples came into contact were either annealed in a 500° C oven, rinsed with the dichloromethane/methanol solution, or both. Nitrile gloves were used at all times in handling the samples to protect both the material and the analyst.

The mixture of sherd powder and HPLC-grade solvent was then placed in an ultrasonic bath for 20 minutes. The ultrasonication procedure ensures that solvent comes into contact with the surface area of the powdered sherd and becomes infused with any organic residues found there. After cooling for five minutes, the tubes were centrifuged at 2000 rpm for 20 minutes. This separates the solvent, now containing the lipids, from the fine clay particles and other inorganic materials. The solvent was then decanted from the centrifuge tube and filtered through a glass pipette stuffed with baked glass wool. This step removed any dirt or pottery remaining after centrifugation. The filtered supernatant was collected in a 50 milliliter glass pear-shaped flask. The pipette was then rinsed with the dichloromethane/methanol solution, and this too was collected in the flask. The rinse was necessary to be certain that as little residue as possible was left in the glass wool or adhering to the glass. Another equal volume of the dichloromethane/methanol solution to sherd weight was added to the centrifuge tube and the process of agitation, sonication, centrifugation, and filtration was repeated.

Once the second supernatant was collected in the same flask as the first and all residues were rinsed out of the pipette and glass wool, the solvent was removed by rotary evaporation under vacuum. When the extract was nearly dry, it was transferred to a pre-weighed 0.5 dram screw-top glass vial with Teflon-lined cap. The flask was rinsed several times with a small amount (approximately two milliliters) of the

dichloromethane/methanol solution to ensure as complete a transfer of extract as possible. The dichloromethane/methanol solution was then completely evaporated under a gentle stream of nitrogen. The vial was weighed again to find to the weight of the total lipid extract (TLE). The balance did not work properly in measuring the TLE of the five initial samples (ES 01-03, 06-07), but was repaired in time to quantify the TLE of the remaining samples.

The extract was next derivatized to silylated esters. Fatty acid methyl ester silylation is a chemical reaction that increases the volatility and reduces the polarity of the fatty acid compounds within the extract, thereby improving their likelihood of separation, detection, and identification using GC and GC-MS (Evershed 1993a). The derivatized residue was created by adding 75 microliters of *N,O*-bis(trimethylsilyl)-trifluoroacetamide (Supelco, Inc., Bellefonte, PA) to the dry total lipid extract. This mixture was heated at 60° C for at least 30 minutes in a dry bath. The derivatizing agent was then evaporated under a gentle stream of nitrogen gas. Finally, the total lipid extract was re-dissolved in 500 microliters of hexane, and the solution was then stored under nitrogen and at 4° C until analysis.

Experimental Controls

The chemicals used in extracted and processing the samples were tested often to find and correct any possible sources of contamination in the laboratory. One analytical blank was run on the chromatograph for approximately every 10 samples. These blanks were prepared in the same manner as the powdered sherds or soils, but without any solid material. A sample of dichloromethane/methanol from the same source as that used to

extract lipids was placed in a centrifuge tube, sonicated, centrifuged, filtered, evaporated, derivatized, and re-dissolved in the same method as the standard protocol discussed above.

Further, portions of an indigenous sherd (ES 01) and a colonial European sherd (ISA 12) were also processed as controls. They were heated in a 600° C oven for at least four hours to decompose any organic residue absorbed into the vessel fragment and then allowed to cool. Since fatty acids begin to degrade around 400° C and other lipids do so at lower temperatures (Rottländer 1990), the heat and time should be sufficient to produce an analytical blank. The control sherds were then processed with the other samples to search for any contaminants or other unexpected compounds that may have been found within the material used to create the pottery or added after excavation.

Non-destructive Protocol

The process of absorbed residue analysis has involved, to this point, destroying the sherd from which the information is gathered. Much like excavating an archaeological site, the method of removing data irrevocably damages the source of that data. Therefore complete vessels, very small collections of irreplaceable pottery, or those sherds with certain traits that warrant long-term protection are poor choices for this technique. Of course, many undecorated body sherds remain salted away in a cardboard box in the corner of some institution, and these may be made available for study. Yet there are instances in which extremely rare samples or museum-quality vessels could provide significant details regarding subsistence patterns and pottery use lives. A few researchers have made attempts to resolve this dilemma, often by scraping with a scalpel

an amount of material less than one gram in weight from the inside of a vessel (e.g., Coyston 2002). But since the outermost surfaces ideally should be discarded to protect against any contaminants, the remaining amount of powder would likely be too small to extract meaningful information. In any case, the vessel is still damaged.

An alternative protocol to the extraction method was developed for this study. Rather than grinding the sherd to a fine powder and then adding the solvent, the solvent was added to the sherd. Sherds large enough to be broken into control and experimental fragments approximately 15 grams in weight were selected. Three sets of these pairs (LEO 01/02; LEO 03/04; and TAM 25a/25c) were created. The control sample of each pair was processed as discussed above. The experimental sherd was dipped into the dichloromethane/methanol solution for three seconds to remove any surface contaminants. Then a large beaker was placed in the ultrasonic bath and within this was positioned the experimental sherd. Enough solvent was poured into the beaker to cover the sherd. The beaker was then draped with baked aluminum foil to prevent splashing, and the whole assembly was ultrasonicated for 20 minutes. After an interim of 10 minutes, it was again ultrasonicated for 20 minutes. The interim was necessary to prevent the formation of any reaction products caused by heating during the ultrasonication process although there was no significant evidence of temperature change.

The solvent, now infused with residue, was decanted, filtered, and collected as described in the standard protocol. The total lipid extracts from both the control (powdered) and experimental sherds were ultimately created following the remaining steps used with the rest of the samples in this study. The experimental sherd itself, however, remained whole and none the worse for wear from its extraction procedure.

It is not known at this time if the hour's worth of soaking in a dichloromethane/methanol solution caused any long term damage to the integrity of the sherd, but both solvents evaporate quickly at room temperature. If the extraction procedure did remove organic compounds from within the sherd without its destruction, even to a lesser degree than with the standard method, this protocol would be of considerable benefit to the researcher seeking to gather data while doing the smallest harm. The method is analogous to remote sensing of archaeological sites: it gathers information without destroying the source.

Instrumental Analysis

After all the extraction and derivatizing had occurred, the samples were analyzed on an Agilent Technologies 6890N gas chromatograph with flame ionization detector (FID). This instrument is used to separate a complex blend of compounds into its various components. The mixture is introduced into an internally coated fused silica column within an oven. The flow of a carrier gas chromatographically separates the constituent compounds during passage through the column while the temperature around the column is gradually increased. Different compounds travel at specific rates based on their molecular weight, polarity, and volatility. As the compounds are carried to the end of the column, the effluent is burnt in a flame, producing ions. The electric current of the ions is detected by the FID. The plot of component abundance versus time creates a chromatogram (see Figure 5.3).

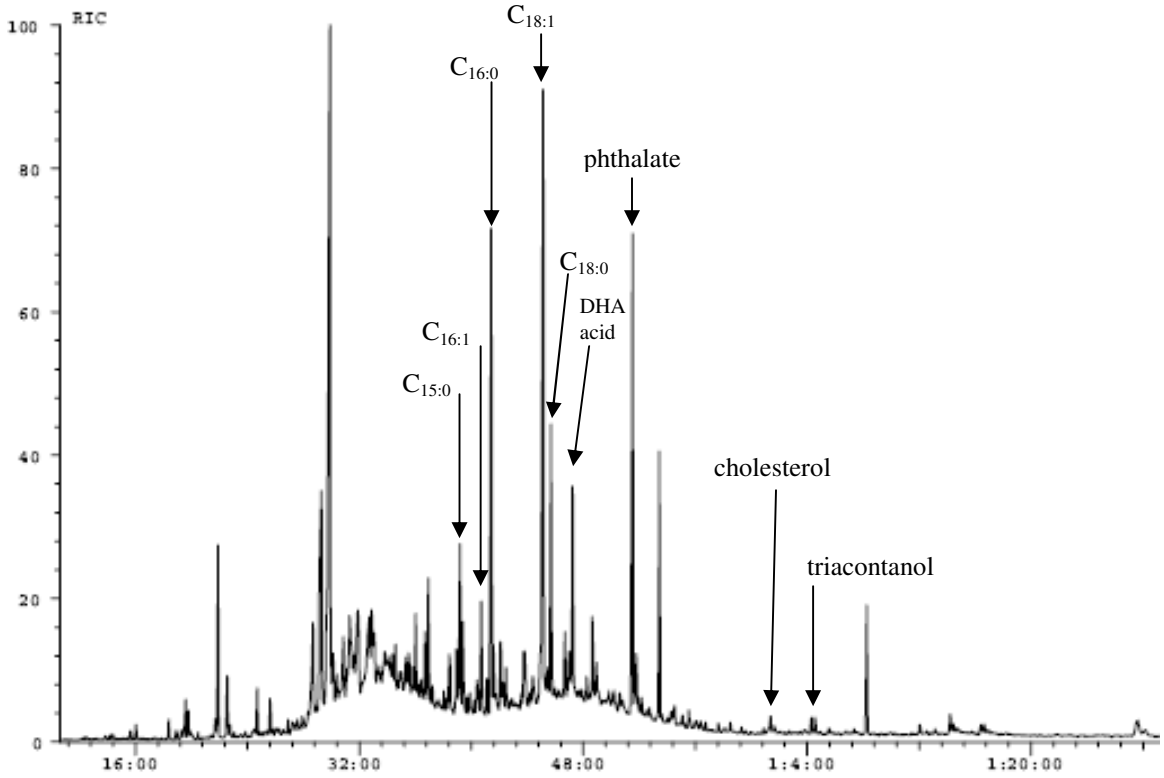


Figure 5.3 Partial gas chromatogram of the total lipid extract from ISA 16.

These peaks are the TMS derivatives from a fragment of an indigenous vessel recovered from La Isabela. The compounds shown include fatty acids (such as $C_{18:0}$), terpenoids (dehydroabietic acid or DHA), plasticizers (phthalate), sterols (cholesterol), and alcohols (triacontanol). The horizontal axis records the time, from eight minutes to 130 minutes, during which separate compounds elute. The vertical axis is a scale, from 0 to 100 percent, of the level of each compound present as compared to the most abundant compound in the sample.

The specific analytical program used in this study started with one microliter sample injected with an auto-injector into a 30 meter long x 0.32 millimeter wide inner diameter fused-silica capillary column from J&W Scientific, coated with a 0.25 micrometer film of (5%-Phenyl)-methylpolysiloxane. Helium was used as a carrier gas, with a flow rate of seven milliliters/minute. The temperature program was set to begin at 60° C and remain at that temperature for one minute, then ramping at 4° C/minute to 320° C, with a 90 minute hold isothermal hold at this temperature. A complete program lasted 156 minutes, significantly longer than any other run time listed in the literature because of the trimethylsilyl (TMS) esters and the targeting of triacylglycerols. The geologists working in the laboratory at Indiana University suggested this type of program, as it is standard in many of their analyses, and the result are compounds sometimes eluting more than two hours into the run.

Before and after each series of samples were injected into the chromatograph, a hexane blank was first run through the column on a similar but shorter program. This accomplished two tasks: an isothermal hold of around one hour cleared any residue remaining from other analytical runs on the column, and the hexane served as a control to measure the sensitivity and performance of the chromatograph. A total of 125 samples, including total lipid extracts from sherds, associated soils, and solvent blanks, were processed for analysis on the chromatograph (see Appendix B). The glass centrifuge tube containing one extract (ISA 14) was broken, and the sample was lost prior before analysis could occur.

Those samples that returned significant peaks signifying a large presence of lipids or compounds of special interest were further analyzed on a Hewlett-Packard 5890 Series

II gas chromatograph interfaced to a Finnigan MAT TSQ 700 mass spectrometer. Mass spectrometric analysis of the compounds as they eluted from the chromatograph allowed for a more conclusive identification of lipids and, where applicable, contaminants. Each compound has a unique spectrum based on its atomic mass and how the compound fragments when ionized (see Figure 5.4). The mass spectrum serves as the characteristic signature or fingerprint for that compound.

The spectrometer was operated in electron ionization mode (70 v), scanning an *m/z* range 50-900 for a total scan cycle time of three seconds. The same fused-silica column was used as that found on the stand-alone Agilent chromatograph. The GC-MS program was slightly different, however, in that the initial 60° C isothermal hold lasted for 10 minutes and the 320° C isothermal hold was 80 minutes in length. A total of 57 separate one microliter samples were manually injected on-column into the instrument (see Appendix C), followed by a one microliter injection of hexane.

Compound Identification

The organic compounds were identified primarily by their mass spectral signatures and their retention time within the chromatograph column. A single library does not currently exist for all the compounds of interest, however, and the total chromatograms produced by several samples were exhaustively investigated spectra by spectra for fatty acids, alcohols, sterols, and other potential biomarkers. Once a reference library was created with the particular lipids used in this study, the quantity of each targeted organic compound present in a sample was calculated using the Automated Mass spectral Deconvolution and Identification System (AMDIS) released by the National

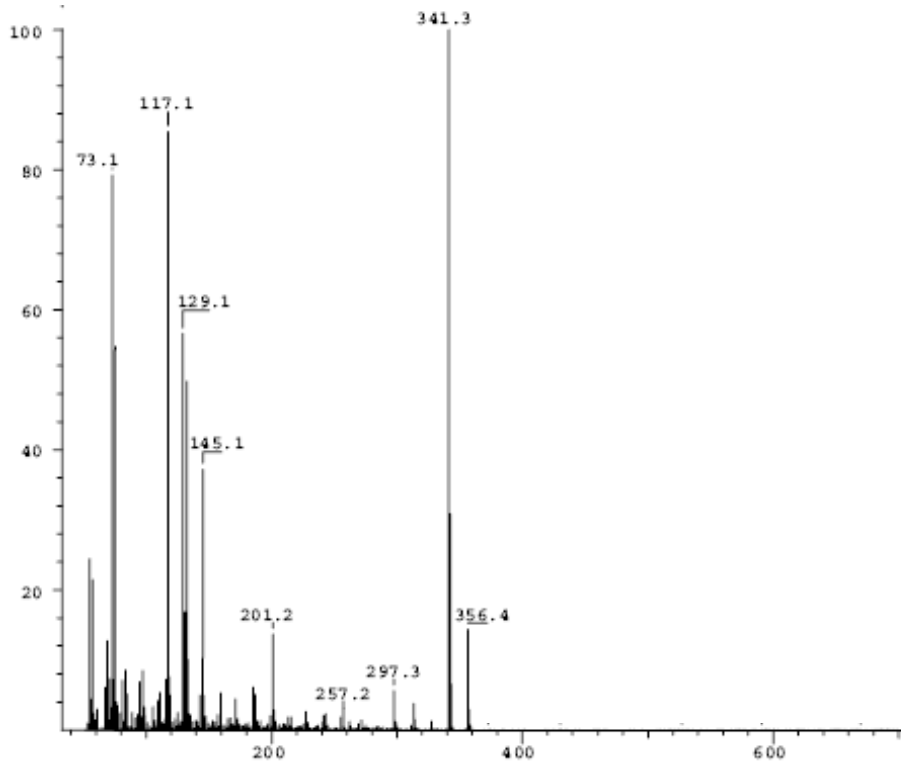


Figure 5.4 Mass spectrum of $C_{18:0}$ fatty acid.

The TMS derivative elutes at 45.6 minutes in Figure 5.3 above. The horizontal axis shows mass over charge (m/z), and the scale of the vertical axis represents a percentage of the most common mass.

Institute of Standards and Technology. After the mass spectrum of each target was viewed and the existence of specific peaks related to the lipid or contaminant were confirmed, the exact amount of that compound was computed by measuring the area under the peak on the chromatogram that marked that compound's presence.

The compounds and their respective amounts were then compared to a wide variety of fatty acid ratios and biomarkers noted in previously published studies. The potential foods types processed in each vessel were classified using this data, and the quantification of organic residues is provided in the next chapter.

CHAPTER 6:

EVIDENCE FOR CULTURAL INTERACTION

Introduction

This chapter presents the general composition of the residues recovered from archaeological ceramics and other samples of interest. The results of the gas chromatography-mass spectrometry (GC-MS) analysis were different from expected. The rate of preservation was less than that found in other recent large-scale studies (Eerkens 2001; Malainey 1997; Reber 2001). This may be due to the particular characteristics of the foods processed within the ceramic vessels. Another explanation, however, may be that the tropical environment found at coastal Caribbean archaeological sites contributes to the increased degradation of organic compounds. Lipid residue in the one other extensive study conducted on material from the Central America region is also described as appearing in extremely small quantities (Coyston 2002). The balance of this chapter considers the potential origins of the organic material and their subsequent removal from the archaeological record.

The issues of preservation and contamination are faced by all archaeologists and are not limited only to those utilizing chemical techniques to learn about the past. It is always a struggle to establish whether material encountered during excavations and in subsequent analyses accurately reflects the original behavior of the people using the

artifacts. Evidence may be altered after the item of interest was discarded and eventually buried under soil, ash, or rock. The data associated with artifacts are also subject to change after recovery, depending on whether items were systematically retrieved by archaeologists or gathered by collectors. When the extra layer of laboratory study is added, the ability to reliably interpret the past is further complicated. The sensitivity of instruments used in biological or chemical examinations necessitates procedures to control for contamination, degradation, and alteration of samples.

Results of GC-MS Analysis

Scientists working with organic compounds use a number of methods to identify fatty acids, alcohols, and other lipids. This can be confusing to archaeologists who are trying to employ biochemical techniques but are unfamiliar with organic chemistry, or even between various biochemists following the conventions of their specific subdiscipline. The systematic name for fatty acids, for instance, is derived from the saturated hydrocarbon with the same number of carbon atoms (Christie 1973). Therefore, the systematic name for the acid with 18 carbon atoms and one double bond is z-9-octadecenoic acid. In other publications it is referred to by its common name, oleic acid. The compound is also known as $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$, which is its structural formula.

Some compounds have two or more common names, and while the systematic name is unambiguous, it is long and unwieldy to use repeatedly in text. Neither name is as clear as the shorthand designation sometimes given to fatty acids. In the abbreviation system used here, and preferred by many researchers, the above compound is referred to

as $C_{18:1}$. While it still describes the carbon number (18) and degree of unsaturation (1, or monounsaturated), the shorthand designation is simpler to understand by non-specialists and easier to read and compare within the text. For the same reasons, the alcohols also have a shorthand designation. An alcohol with 18 carbon atoms, known as octadecanol or stearyl, is referred to here as OH C_{18}

Over the course of this project, 125 total samples were processed and analyzed using gas chromatography. Of this, 70 were from indigenous vessels, 25 were from contact period European vessels, 13 were soil samples taken from sherds or directly from sites, and two charcoal samples were recovered from the interior of two of the pottery fragments. Another 14 experimental samples were analyzed, consisting of different chemicals and solvent rinses of equipment utilized in the laboratory. The average mass of the sherds was 13.68 grams, and the mean total lipid extract for each sherd was 0.0139 milligrams. The total lipid extracts from the other samples were much smaller. The charcoal yielded a mean of 0.0077 milligrams, the experimental samples produced 0.0059 milligrams on average, and an average of 0.0025 milligrams were recovered from the soils. The characteristics for each sample are listed in Appendix B.

The gas chromatograph cannot be used to independently and precisely identify each compound within the residue. As a result, many chromatograms were generated but additional analysis had to be done. Still, for certain sections of this analysis, the gas chromatograms of 15 sherds were included in order to shed more light on particular questions.

Approximately one half of the total samples, a subset of 55, were selected for further investigations using GC-MS. These included analyses of 35 indigenous vessels

and 12 associated with the colonists. Five soil samples were analyzed so that comparisons could be made between compounds found absorbed within the sherds and those from material adhering to or surrounding the sherds. The residue from two charcoal samples and one experimental sample was also studied. The assessment of which samples were run using GC-MS was made with several criteria in mind. Foremost among these was an evaluation of the individual chromatogram. Those samples that formed clear and distinct peaks signifying appropriately high concentrations of target compounds were chosen. But the variety of peaks was also taken into account, so as to create a broad library of lipids and other organic compounds. Now that a library of expected elution times for the compounds used in this study has been created and checked for accuracy, special software can be obtained to analyze the remaining chromatograms in the future.

At least one fatty acid, alcohol, or other organic compound was readily observed in every sample analyzed using GC-MS, although the number and intensity varied widely. Four samples contained such a low concentration of fatty acids and alcohols that they could not be used in most of the residue identification procedures. One of these was the "blank" control sherd (ISA 12) that had its lipids purposefully removed by baking for four hours in a 600° C oven. Another was a burén from Cangrejera Oeste (CO 01), the thick ceramic griddle presumed to have been used for grilling cassava bread. This artifact would not be expected to absorb much oil due to the dry cooking process, although the other buréns studied did yield fatty acids. The third sherd was taken from a Chican bowl recovered from the surface at El Perenal. One possible reason for the absence of lipids in this sample is degradation due to time of burial or soil conditions.

Yet since the other sherds from the site preserved organic compounds, this is doubtful. It is more likely that the vessel from which the sherd came was not used for cooking or storing foods, or the foods processed within them did not contain high levels of fats or oils. It may have been made strictly for a ritual purpose or to hold non-food material. The final sample was soil from sherds collected near Punta Rucia (ES 09). The sherds associated with this sample come from a burial context and are discussed further in the next chapter.

The fatty acid compounds recovered from more than 50 percent of the samples were $C_{14:0}$, $C_{15:0}$ (including branched isomers), $C_{16:0}$, $C_{17:0}$ (including isomers), $C_{18:0}$, and $C_{18:1}$. Additional fatty acids were observed less frequently (see Table 6.1). Long-chained saturated fats (e.g., $C_{22:0}$) and all monounsaturated fats (e.g., $C_{22:1}$) were relatively uncommon, both in terms of the samples containing those fatty acids and in the proportion of those compounds to all the fatty acids recovered. The only polyunsaturated fat, the type with more than one double bond, encountered in any of the samples was $C_{18:2}$. The lack of polyunsaturated fatty acids was expected and has been noted in other studies (Eerkens 2005; Evershed, et al. 1992). The long-chain and unsaturated fats are comparatively unstable and thus degrade more easily due to oxidation. Any such compounds present probably changed to dicarboxylic acids or epoxy acids over time or were cleaved to give lower molecular weight alcohols and alkanes, or became insoluble after bonding with other compounds (Frankel 1980; Hudlickey 1990).

Although they are rarely discussed in the literature, fatty alcohols were present in many of the analyzed samples and at relatively high concentrations. All of the even-numbered alcohols from OH C_{14} to OH C_{32} were observed in over half of the samples

Table 6.1 Fatty acids recognized through GC-MS analysis.

Fatty Acid	*Samples Containing Fatty Acids**		*Portion of All Fatty Acids Recovered*
$C_{12:0}$	48.8%	(n=21)	0.5%
$C_{13:0}$	4.7%	(n= 2)	<0.1%
$C_{14:0}$	76.7%	(n=33)	10.6%
$C_{15:0}$	62.8%	(n=27)	1.0%
$C_{16:0}$	86.0%	(n=37)	62.5%
$C_{16:1}$	30.2%	(n=13)	1.2%
$C_{17:0}$	55.8%	(n=24)	3.4%
$C_{17:1}$	2.3%	(n= 1)	<0.1%
$C_{18:0}$	81.4%	(n=35)	15.9%
$C_{18:1}$	51.2%	(n=22)	2.4%
$C_{18:2}$	9.3%	(n= 4)	0.1%
$C_{19:0}$	18.6%	(n= 8)	0.1%
$C_{20:0}$	41.9%	(n=18)	1.1%
$C_{20:1}$	2.3%	(n= 1)	<0.1%
$C_{22:0}$	32.6%	(n=14)	0.3%
$C_{22:1}$	4.7%	(n= 2)	<0.1%
$C_{24:0}$	30.2%	(n=13)	0.5%
$C_{24:1}$	2.3%	(n= 1)	<0.1%
$C_{26:0}$	46.5%	(n=20)	0.1%
$C_{28:0}$	30.2%	(n=13)	0.1%
$C_{30:0}$	16.3%	(n= 7)	0.1%
$C_{32:0}$	7.0%	(n= 3)	<0.1%

*Percentages are based on 43 samples that yielded any fatty acid after GC-MS analysis.

containing any alcohols (see Table 6.2). Most of the alcohols encountered (76.4 percent) came from only three compounds: OH C_{14}, OH C_{16} and OH C_{18}. Odd-numbered alcohols (OH C_{13} to OH C_{29}) were also present, but not recorded at this time due to their rarity. They appeared in no more than five to ten samples, and at this time a literature search has found no examples of odd-chained alcohols being used in diet reconstructions.

Table 6.2 Alcohols recovered through GC-MS analysis.

Alcohol	*Samples Containing Alcohol**		*Portion of All Alcohol Recovered*
OH C_{13}	40.4%	(n=21)	2.4%
OH C_{14}	92.3%	(n=48)	14.3%
OH C_{16}	96.2%	(n=50)	28.9%
OH C_{18}	94.2%	(n=49)	33.2%
OH C_{20}	73.1%	(n=38)	3.5%
OH C_{22}	80.8%	(n=42)	3.1%
OH C_{24}	76.9%	(n=40)	3.2%
OH C_{26}	75.0%	(n=39)	3.4%
OH C_{28}	75.0%	(n=39)	2.7%
OH C_{30}	61.5%	(n=32)	3.9%
OH C_{32}	63.5%	(n=33)	1.3%
OH C_{34}	38.5%	(n=20)	0.2%

*Percentages are based on 52 samples that yielded any alcohol after GC-MS analysis.

Sources of Contamination

Phthalate

The most common identified compound was phthalate, which is used to facilitate the production and improve the performance of modern plastics. Phthalate was found in every sample (see Table 6.3), probably introduced through the use of zip-top plastic bags to transport and store the artifacts and soils or from any of the artifacts that were marked with nail polish during processing. The practice of wrapping artifacts in foil after recovery did not appear to reduce the prevalence of the compound. Even the "blank" control sherd discussed above contained phthalate. In two-thirds of the samples (n=36) however, the amount of phthalate present was less than five percent. The ubiquitous

compound actually served as a reference point in post-analysis, confirming the retention times of other compounds and the success of file conversion programs.

Table 6.3 Other compounds recovered through GC-MS analysis.

Compound	*Samples Containing Compound**		*Amount of Compound Relative to Total Fatty Acids and Alcohols*
Cholesterol	70.9%	(n=39)	2.1%
Dehydroabietic acid	47.3%	(n=26)	5.3%
Phthalate	100.0%	(n=55)	87.8%
Squalene	72.7%	(n=40)	0.9%
Unknown 1	18.2%	(n=10)	0.2%
Unknown 2	1.8%	(n= 1)	<0.1%

*Percentages are based on all 55 samples analyzed.

Cholesterol

Two important biomarkers, cholesterol and squalene, are evidence for an animal presence. Cholesterol is found in the fats of most meats, and squalene can be derived from cartilaginous fishes such as sharks and rays. An additional source for both of these compounds is human skin oil. Thus, the presence of the biomarkers could be associated with food made from animal tissue or contamination from handling the artifact after recovery.

Cholesterol levels were absent or less than one percent in abundance in about half of the samples (n=27) and relatively low in the majority, averaging 2.1 percent of all fatty acids and alcohols (see Table 6.3). The frequency was over 10 percent in just three archaeological samples, each of colonial European origin (two from La Isabela and one from Las Coles). Further, as will be discussed in the next chapter, those samples that

exhibited cholesterol also met other conditions for the presence of mammal or fish meat. The co-occurrence of two measures of animal tissue compounds present in the residues of the vessels suggests that the cholesterol was absorbed as a part of the cooking process and not as a modern contaminate.

To support this claim, the control sherd had no cholesterol residue and the experimental sample contained the largest absolute amount. The experimental control was created with the intention of assembling as many human contaminants as possible. A volunteer's bare hands were rinsed with the solvent methanol, and this solution was combined with hair and scalp particles. The sample was then processed via the standard protocol for this study. Finally, the total lipid extract was analyzed for the presence of non-food residue and other possible contaminating compounds. The measured area under the cholesterol peak in the experimental sample was three times greater than the next largest area, and over 40 times the size of the average peak area of all archaeological samples. One may feel confident, therefore, in assuming that the relatively low abundance or occurrence of cholesterol is not caused by post-recovery contamination.

Squalene

Squalene, a common component in human skin oils as well as in some animal oils, is present in almost three-quarters of the total sample, although usually at a low level (see Table 6.3). Only eight archaeological samples exhibited levels greater than 10 percent, and these were from a variety of sites (three from El Tamarindo, two from Las Coles, and one each from Edilio Cruz, La Isabela, and Punta Rucia). The compound is

missing or below one percent of abundance in almost half of the chromatograms (n=26), and the total amount recovered is less than one percent of all fatty acids and alcohols.

The control sherd is among those that have no squalene. Since it was handled in the exact same manner after heating as the other archaeological samples, and because it also does not contains cholesterol, it appears that the actions taken to reduce contamination in the laboratory were successful. The strict protocol of glove use, solvent rinsing, and annealing of laboratory equipment was implemented as other researchers have claimed that the most common corruption of sample purity can occur due to handling and result in the presence of non-degraded squalene and cholesterol (Evershed 1993b; Oudemans and Boon 1991).

The absence of squalene from the experimental control, however, is surprising. In that instance, contaminates were deliberately sought. Squalene is one element of sebum, an oily substance that protects and waterproofs hair and skin. It could be that since squalene is not directly produced in the palms or fingers of the hand, it is not as strong of a sample pollutant as was feared. If this is the case, the presence of squalene may in fact be a biomarker of the production and use of cartilaginous fish in the past. Sharks and rays produce a large quantity of squalene in their livers, and are currently hunted to harvest the compound for use in vitamins. Only one of the eight samples with squalene abundance greater than 10 percent, however, also meets the other criteria for identifying residue from fish oils. The evidence for aquatic animal use is not as well studied as that of other food classes, as discussed in Chapter 7. Further research both into biomarkers for marine creatures and the association of squalene with food production (it is found in

small quantities in olives as well) as well as contamination would benefit the technique of absorbed residue analysis.

Dehydroabietic acid

Another interesting signature compound was encountered during the course of this analysis. Dehydroabietic acid (DHA) is a diterpenoid acid, and thus a biomarker for coniferous trees (especially those that do not produce amber, such as pine, fir, and spruce) and their products. As diterpenoid resins from pines age, they oxidize and result in the production of abietane diterpenoid acids, which are further degraded to form DHA (van den Berg, et al. 2000). A previous study has noted this compound in an archaeological sherd and interpreted its presence as evidence of rendering pitch or tar through the boiling of resin (Eerkens 2002). Other possible sources of introduction may have come through transporting pitch or tar (Robinson, et al. 1987), burning pine-based incense (Stern, et al. 2003), or sealing a vessel with resin (Meiggs 1982). Additionally, pitch in liquid form has been used throughout the history of wine-making as a flavor additive. The resin residue may come from a decision to enhance, or mask, the taste of contents stored within a container.

The distribution of DHA in the samples analyzed for this project, though, suggests a reason for its appearance unrelated to cuisine or other behavior of people in the past. The compound was absent or had an abundance of less than one percent in nearly three-quarters of the samples (n=41). The remaining 15 samples with elevated levels of DHA, consisted of all 11 of the lipid-containing colonial European sherds and an indigenous sherd also from La Isabela (see Table 6.4). Two of the other three sherds were from

Punta Rucia and the last was excavated at El Tamarindo. The fact every one of the La Isabela and Las Coles sherds showed elevated levels of DHA regardless of cultural origin, while the vast majority of samples from all other areas did not, implies something unique was happening at those sites.

Table 6.4 Samples with significant presence of dehydroabietic acid.

				Dehydroabietic Acid	
Sample	***Site/Origin***	***Sherd***	***Decoration***	***Area***	***%****
TAM 05	El Tamarindo/Indigenous	jar rim	Chican	13188	1.06
ES 06	Punta Rucia/Indigenous	bowl shoulder	Meillacan	74189	2.63
ISA 10	Las Coles/European	vessel body	undecorated	123863	15.83
ISA 04	Las Coles/European	jar neck	incised	200205	37.74
ISA 16	La Isabela/Indigenous	vessel body	undecorated	311233	16.70
ISA 31	La Isabela/European	bowl rim	undecorated	570870	1.77
ISA 02	La Isabela/European	cantimplora body	undecorated	811820	2198.39
ISA 05	La Isabela/European	bowl body	undecorated	1081638	584.07
ES 07	Punta Rucia/Indigenous	bowl rim	Meillacan	1405349	4.38
ISA 15	La Isabela/European	bowl rim	cord-marked	1535510	219.96
ISA 01	La Isabela/European	vessel shoulder	undecorated	2993406	121.28
ISA 23	La Isabela/European	jar neck	ridged	3031193	80.09
ISA 11	Las Coles/European	jar neck	ridged	3918707	40.89
ISA 25	La Isabela/European	vessel body	undecorated	10680694	166.50
ISA 09	La Isabela/European	jar rim	incised	30621998	88.76

*Percentages are based on amount relative to total fatty acids and alcohols in sample.

There are a number of possibilities to explain the presence of relatively higher levels of DHA absorbed within the European sherds. The addition of the compound may have occurred at any of the periods during the vessels' useful lives: manufacture, transport, use, or discard. The sherds may have also been contaminated after they entered the archaeological record or subsequent to their excavation. Since all of the sherds from La Isabela and Las Coles, with the exception of the control sherd, exhibited DHA, it is

reasonable to assume the compound was absorbed into all sample at the same stage of use life.

Among the least likely explanations is the addition of DHA during the initial firing of the vessel. The use of pine, spruce, or fir as fuel for a kiln would result in smoke that could carry DHA to the surface of the heated clay. The temperatures at which non-glazed earthenwares are fired is relatively low, typically around 600-900° C. The clay body of the vessels would readily absorb many airborne compounds during this time, yet the heat would have also degraded DHA as evidenced by the lack of the acid in the control blank. Further, soft pine firewood is a far less desirable fuel source compared to deciduous hardwoods in terms of levels of heat achieved and length of burn time. Ceramics made in the Andalusian region, from which Columbus's fleets were provisioned, typically used olive branches and even the pits and skins of the olive as fuel, although furze (*Ulex* sp.), an evergreen, is used in other areas of Spain (Lister and Lister 1987). But all the unglazed wares recovered from La Isabela were almost certainly manufactured locally (Deagan and Cruxent 2002a). Whether the vessels were fired in Europe prior to their arrival in Hispaniola or while on the island, more suitable sources of fuel were abundantly available.

If every one of the vessels was in fact transported to the La Isabela area aboard ships, they would certainly have been in close vicinity to sources of DHA. Anchor cables and other lines were tarred to protect against deterioration caused by water. Many of the wood planks of the ship above and below decks would have been sealed with tar and the joints stuffed with oakum or luting, a type of caulk made of tarred strands of rope-like material. As discussed in Chapter 3, sailors lived on the main deck among the ship's

equipment and utilized any surface or object at hand. Moreover, barrels or olive jars in the hold, the cardboard boxes of that era, could have been sealed with tar or pitch to make them impervious to water. Pottery may have been packed within similar containers or come into contact with resin spilled from neighboring casks and jars.

Even though Columbus did complain of leaky barrels, it is improbable that every European sherd analyzed in this study was in close proximity below decks and effected by the spills of wine that occurred. The sherds were almost certainly not owned by one individual, and they were recovered from several excavation units separated by distances of a kilometer. Even more doubtful is that the vessels picked up contaminating DHA from short-term and interrupted exposure to resins from the surfaces of the ship or the lines aboard. The voyage lasted three months, which may have seemed long for the passengers but likely would not be adequate for contamination due to contact at ambient temperatures.

The dissimilar forms and different presumed functions of the European-origin vessels preclude their use for tar and pitch production or sealing with resins. The sherds were from bowl, jars, a cantimplora (canteen) form, and other undetermined shapes. These vessels served several capacities in the kitchen or at the table, as shown by a diverse range of lipids found in each sherd. The cantimplora, especially, would have been of little use in rendering tar or pitch from pine products. While it could be argued that the cantimplora may have been sealed with some sort of resin, this would have only made sense if it was used as a wine flask. Evidence for water purposefully flavored with pine is absent in known ethnohistories of the time. In any case, sealing defeats the

purpose of a canteen, which is shaped to increase the ratio of surface area to volume so that evaporation can cool the contents.

Since every sherd contained DHA in the La Isabela and Las Coles samples, regardless of where they were recovered or what vessel type they were from, if the Europeans purposefully added resins, it can be extrapolated that they did so to all the ceramics they created or owned. This is difficult to believe. Instead, a potential unintentional source of the residue from pine resins could be from smoke originating from the burning of surrounding buildings. Columbus returned from an expedition in March 1494 to find two-thirds of the settlement destroyed by fire (Deagan and Cruxent 2002b). Smaller fires happened periodically before and after this event, as one would expect with closely packed, roughly built houses made mostly of wattle and daub with thatch roofs. The rebel Roldán sacked La Isabela in May 1497. Along with breaking into the storehouse and other buildings to take supplies of food and weaponry, fires were probably also lit in the confusion. It is possible that the vessels were near enough to the heat to be susceptible to absorbing pine resins from the smoke of burning pine material. Unfortunately, the species of trees used in constructing the houses remains a mystery.

The presence of DHA may have another inadvertent source, like the soil in which the vessels were buried after discard or another related environmental condition common only to the two sites. Yet the natural setting of La Isabela and Las Coles is not demonstrably unlike those found at the other sites, some of which are less than two kilometers away. None of these sherds had visible residue adhering to the surface, and the outer few millimeters of ceramic material were removed during processing. It is unlikely, then, that the presence of DHA is from sap that had fallen on each of the sherds.

The two most likely scenarios that explain the DHA residue are both related to the post-excavation treatment of the sherds. The samples from La Isabela and Las Coles all share one single variable the others in this study do not – they were stored after excavation in a locally made wood chest. The carcass, drawers, and doors were constructed near the museum at La Isabela and assembled within the room where the chest remains at this time. The wood used appeared to be unfinished pine. The sherds were placed in shallow boxes or directly on the wood bottoms of the drawers and stored within the chest for approximately 15 years before being selected for this study.

During this time, the chest was covered only by a thin roof and cement block walls that were open near the eaves. The heat of the Dominican summer was certainly noticeable at the time of collection and aggravated by the conditions of the room. It may be possible that the sherds absorbed resin acids from the wood in which they were stored, instead of from any material stored or processed within the vessels. Although this is opposite from the manner in which most residues are absorbed, it is still a distinct possibility for the presence of DHA. This is especially true when one considers the indigenous sherd from La Isabela analyzed by GC-MS also exhibits a relatively high level of DHA in relation to all other fatty acids and alcohols (16.7 percent). This sample would not have been made with the others and as such would not have absorbed DHA during firing with pine fuel. Nor would it have been contaminated during transport on European ships. The excavators of La Isabela claim that the majority of Taíno ceramics recovered there date to a time prior to the arrival of the colonists (Deagan and Cruxent 2002a). There remains a chance the vessel from which the sherd came was present and in use during the fires at the sites, but even then it is not certain that smoke would provide

enough airborne DHA to come into contact with vessel walls at such a high concentration, nor if the ceramic would have been in a condition amenable to absorption. The sherd, on the other hand, was collected from the same drawers as the other samples from La Isabela and Las Coles and its long contact with the pine used in the construction of the chest is known.

The excavators of the samples from La Isabela and Las Coles are also the only ones who used nail polish and correction fluid in cataloguing their recovered sherds. Often archaeologists brush a small bit of nail polish on light-colored artifacts or a line of correction fluid on darker material so that a catalog number can be applied without causing irreversible harm. Nail polish is then used to seal the number and protect against accidental erasure. Another researcher has noted a contaminate, possibly derived from resins, in sherds processed with nail polish (Coyston 2002). It that study, the contaminant seems to have been carried by solvents within the polish further into the ceramic fabric than just the surface where it was applied. The extra care taken to remove the polish from the surface with a drill or brush may not eliminate all the contamination.

The contaminant in the Coyston study eluted at nearly the same time as $C_{16:0}$ fatty acid. The peak for DHA, on the other hand, consistently elutes at a later time, between the appearance of $C_{18:0}$ and $C_{19:0}$ fatty acids. Further, although some of the sherds from La Isabela and Las Coles were marked with polish, others were not. Despite this, DHA was present in all the samples examined. It is possible that DHA was introduced to the sherds via a cataloging method, but this contention is not strongly supported. The appearance of the compound does not match the circumstances described in Coyston, and it occurs in every sherd, regardless of visible evidence of polish.

The remaining three sherds were never cataloged with nail polish. The two from Punta Rucia were stored for some time in newspaper before collection for this study. Paper mills are a notorious source of DHA pollution found in streams. The compound, or the abietane diterpenoid acids from which it is derived, may be volatile enough to be absorbed into the ceramic matrix without the catalyst of traditional cooking processes. A similar concern was raised by Oudemans and Boon (1991) with regards to contamination that may be difficult to recognize but occurs during post-excavation processing of artifacts, such as drying objects on paper. The time of contact with the newspaper was less than two years and there were no forces such as heat or solvents present, making this a less than perfect explanation.

These two sherds, and the sample from El Tamarindo, have a relative percentage of DHA between 1.1 and 4.3 percent (see Table 6.4). The amount is more likely to be genuine than the elevated levels found in La Isabela and Las Coles sherds (mean=297.7, median=84.43). The El Tamarindo sherd and one of the Punta Rucia sherds have a suite of fatty acids and alcohols as well as DHA, suggesting the vessels from which they come were also used for some type of food production. A credible rational for the presence of resin in these sherds is that they were used by the Taíno for a ritual purpose. The Punta Rucia material was found in association with the skeletons of two humans, and thus may have held offerings containing pine-based material, such as copal or another incense. Alternatively, the vessels may have been sealed with pitch to ensure the lasting preservation of materials provided for the dead.

The surprising presence of DHA in relative abundance presents questions that should be studied further. Most of the explanations presented above are testable

hypotheses. Experiments can be done to determine the level of contamination to replica pottery through pine smoke. Also, blank sherds can be placed in direct surface contact with samples of pitch, tar, unfinished pine boards, and newspaper for a length of time and at elevated temperatures to test the tendency to absorb resin acids. In particular, research done on potential contamination caused by chemicals used in post-excavation processing, drying artifacts on newspaper and storing them on pine shelves, all common occurrences in the recent history of archaeology, would provide beneficial insight into the observed presence of resins.

Soils

A further source of contamination is the soil from which the artifacts have been recovered. This has been studied by several researchers, nearly all of whom have reported only low occurrences of lipid contribution by the burial environment (e.g., Deal and Silk 1988; Heron, et al. 1991). Condamin and colleagues (1976) were among the first to compare fatty acids from within sherds to those in adjacent soil. They found the concentration from the interior of the vessel was much higher than that from the dirt collected off the exterior surface. Based on the differences between the lipids present and their amounts, it is believed that the effect of soil contamination is negligible. A qualitative analysis of the soil/sherd sets in this study seems to provide additional support. Close scrutiny of the fatty acid contents of four sets of soil and sherd samples from four different sites (Edilio Cruz, Loma de Leonardo, Punta Rucia, and El Tamarindo) shows a diverse suite of lipids in each (see Table 6.5). These results were

Table 6.5 Relative percentages of fatty acids identified in sets of soils and sherds.

	LEO 07 soil	*LEO 02 sherd*	*LEO 04 sherd*	*ECZ 15 soil*	*ECZ 05 sherd*	*ECZ 11 sherd*	*ECZ 13 sherd*
$C_{12:0}$			6.72	2.54		100.00	
$C_{13:0}$							
$C_{14:0}$		1.63	47.45	24.36	5.33		4.88
$C_{15:0}$		1.54	0.72	3.68	1.29		
$C_{16:1}$		0.81					
$C_{16:0}$		64.77	36.75	35.63	70.85		92.74
$C_{17:0}$		1.31	1.90		0.73		
$C_{18:2}$		1.84	1.10				
$C_{18:1}$			1.56	4.99	5.73		
$C_{18:0}$		9.28	3.64	13.05	13.09		2.37
$C_{19:0}$		0.34			0.57		
$C_{20:0}$		4.12			2.01		
$C_{22:1}$							
$C_{22:0}$		1.62			0.40		
$C_{24:0}$		6.88		6.46			
$C_{26:0}$	100.00	4.70	0.08				
$C_{28:0}$		1.17		9.29			
$C_{30:0}$			0.08				
$C_{32:0}$							
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 6.5 (Continued.)

	ES 10 soil	*ES 04 sherd*	*ES 07 sherd*	*TAM 27 soil*	*TAM 21a sherd*	*TAM 22 sherd*	*TAM 23a sherd*	*TAM 24 sherd*
$C_{12:0}$			1.40		0.15	1.04		
$C_{13:0}$						0.40		
$C_{14:0}$	11.66		26.51	19.02	9.73	26.13	13.91	1.08
$C_{15:0}$	2.68			4.86	0.63	2.00	7.06	1.19
$C_{16:1}$	9.38	78.64			0.03	0.80		
$C_{16:0}$	44.02	21.36	72.09	44.07	78.40	39.99	33.16	68.98
$C_{17:0}$				2.41	0.36	4.71	4.48	1.75
$C_{18:2}$								
$C_{18:1}$	15.81			2.46	0.44	1.28	5.56	
$C_{18:0}$	7.89			20.27	8.56	14.20	20.08	26.00
$C_{19:0}$					0.31	0.37		0.24
$C_{20:0}$				0.23	0.61	0.31	1.99	0.22
$C_{22:1}$								
$C_{22:0}$				0.37	0.68		1.48	0.37
$C_{24:0}$	7.72				0.09	2.50	8.90	
$C_{26:0}$	0.85			2.46		1.46	3.38	0.06
$C_{28:0}$				3.84	0.01	2.12		0.10
$C_{30:0}$								
$C_{32:0}$						2.68		
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

obtained after the surfaces of the analyzed sherds were removed with a drill in the attempt to eliminate potential contaminants from the burial environment.

Preservation Potential of Various Samples

This study intentionally selected samples from a number of different recovery contexts for the purpose of testing the feasibility of residue analysis on commonly available archaeological materials. Samples were taken directly from a supervised excavation, but others were from museum storage or simply collected from the surface of the ground during a region-wide reconnaissance. In this way, comparisons could be made among the various potential sources of residue data. Except for one special instance discussed below, there was no strong association between the abundance of lipids and the context from which they came. There were a total of 47 sherds analyzed using GC-MS and containing fatty acids. The top quartile of these included six excavated sherds, three stored after subsurface collection, and two obtained from surface surveys. The bottom quartile has exactly the same composition.

Excavated sherds were a distinct minority in those samples that showed no fatty acids, but this result may be biased by the types of sherds recovered. Vessel fragments encountered during excavation were selected for use in this research on the basis of their likelihood to contain lipids, primarily from shoulder and neck areas. The rarity of artifacts found on the ground surface dictated a sample of convenience. As a result, it appears that if fatty acids are indeed present, the data from surface surveys can yield information regarding vessel use. Surface surveys are limited by their lack of contextual information and ability to date artifacts relative to others. On the other hand, they are

much cheaper to conduct, wider in their scope of geographical area covered, only minimally invasive and thus more readily permitted by private land owners, and are faster to accomplish. Consequently, surface collected material and the use of artifacts already excavated and stored in repositories allow for less intrusive and more cost and time effective manner of collecting samples for absorbed residue analysis.

The exception mentioned above regarding context and preservation concerns three sherds recovered from a fresh water spring at Los Hoyos de Molina, in the northeast of the Dominican Republic. These sherds were collected by a Dominican colleague and volunteered for this study by officials from the Museo del Hombre Dominicano. The depth of their location when recovered was not provided with the samples. No fatty acids or other lipids were found during GC analysis. One of the sherds was a base and therefore not expected to have a high abundance of fatty acids (Charters, et al. 1993; Evershed, Charters, et al. 1995), but the lack of any organic residue, even from a submerged context, was unanticipated.

Lipids are able to survive for some time in water. Pine resins associated with ceramic vessels and organic material have been recovered from ships sunk circa 2600 years ago (Robinson, et al. 1987), a variety of lipids have been noted from bog bodies buried some 2300 years ago (Evershed 1990, 1992), and fatty acids have been found within a 1400 year-old submerged ship's sounding lead (Rosen, et al. 2001). In each of these situations, the artifact was protected by anaerobic conditions that slowed the degradation rate of organic matter (see Chapter 4). However, not all residues are as resistant as others. Shorter chain lipids are more soluble in water and also more frequently lost due to microbial activity (Fukushima, et al. 1987). Fatty acids in general

are less stable in submerged environments than other organic compounds such as sterols (Cranwell 1981).

It is possible the sherds recovered from the spring at Los Hoyos de Molina were not submerged deep enough to afford them protection against hydrolysis or oxidation. Another culprit for degradation is microbial activity, generally the greatest factor in the decay of organic matter (Eglinton, et al. 1991). Any or all of these reactions may have caused the observed absence of residue absorbed into the sherds. It would be unfortunate if vessels recovered from water at less than extreme depths cannot provide data relating to substances contained within them. The Greater Antilles and the Yucatan Peninsula have many *cenotes* or sinkholes that provided the inhabitants of these areas fresh water and also ceremonial space. A wealth of artifacts has been retrieved from these sources which are ideal for organic residue analyses.

On the other hand, the sherds may have not have contained any material prior to deposition. If the vessels were used only for water gathering or transport, no significant organic residue would likely accumulate within the walls. The sherds are from a bowl, a jar, and an undetermined form, so for at least one of the samples this explanation is reasonable. Alternatively, they may be from objects thrown into the spring for ritual purposes. The Taíno are thought to have used other sinkholes in the area for nonutilitarian activities, although the comparable artifacts at those sites were at times broken and repaired, worn with apparent use, or contained seeds and other materials (Beeker, et al. 2002; Conrad, et al. 2001).

Since the original uses of the vessels from Los Hoyos de Molina cannot be known, further research into the preservation of absorbed residue submerged at shallower

depths would be warranted. Objects that serve as offerings may contain some of the more unique substances associated with ritual life. Ethnohistories tend to be limited in their interpretations of ceremonial behavior because the documents are being recorded by an outsider that may not know enough of the culture to understand its complexity. If it is possible to recover the ingredients or compounds that distinguish sacred procedures, knowledge about the belief systems of different peoples could be greatly expanded.

Outcome of Non-destructive Protocol

The same qualities that protect absorbed compounds and make possible their preservation over thousands of years ultimately leads to their destruction, as well as that of the sherd in which they are found. Lipids are hydrophobic and the pores within the ceramic fabric into which they are absorbed are very small. Thus, the typical procedures used to extract organic material from within vessel walls involve the use of strong chemical solvents and the pulverization of a fragment of material. The homogenization of the sherd using a mortar and pestle is thought to be the most efficient manner in which to remove the target compounds, as it increases the surface area of ceramic fabric to the solvents. Although the powdered clay is not completely destroyed in this analysis, as would occur in some archaeological dating techniques, it has lost any potential for future analysis of its decoration, size, or shape. The information gained from absorbed residue studies provides a picture of the use of materials in the past, but it comes at the expense of the artifact.

The destructive method of extraction has limited the number and types of artifacts examined. Intact museum quality vessels are rarely selected for analysis, even though

they may be of particular shapes or with specific decorations that would be of interest to study. Conservators of small collections of sherds or those of samples that are difficult to replace are also loath to part with their material. Investigators have employed a number of novel approaches to lessen the impact of sample removal or increase the efficiency of analysis on sherds already singled out for destruction. The latter approach was used in this study. A set of 18 collected sherds were divided in half with one portion used in the current research and the other sent to the research reactor at University of Missouri to be analyzed in terms of their clay composition and its probable source (Conrad, et al. 2005). Other attempts to increase the information gained from sherds include decreasing the amount of material needed for analysis. In the earliest attempts at extracting absorbed residue, sample sizes of 100 grams were used (Condamin, et al. 1976). Now amounts as small as one to three grams are all that are necessary (Regert, et al. 2003). Sherds have also been split into two millimeter layers from the outer to the inner surface in order to evaluate extraction protocols and concentration gradients (Stern, et al. 2000). A similar tactic was used in this research to study the absorption rate through thick ceramic buréns. These efforts make the most efficient use of the sherds available.

Techniques for collecting samples from intact or reconstructed vessels have also been developed. Small samples (around two grams) have been taken from certain locations within artifacts rebuilt from recovered sherds in order to compare lipid concentrations in different regions of the pot or bowl (Charters, et al. 1993). The ceramic fabric could then be repaired with clay to mask the missing fragments. Based on the results, suggestions were made for future sampling strategies of various vessels. An innovative method of sampling from intact pots (albeit replicas) involved drilling one

centimeter diameter holes through the wall (Charters, et al. 1997). The ceramic was collected and processed through standard protocols. The integrity of the vessel is maintained, for the most part, yet absorbed residue analysis could be conducted. A more common practice is to use a scalpel to remove about a gram of material from within the interior of a vessel (e.g., Coyston 2002). As discussed in Chapter 5, this technique must incorporate the practice of discarding the outermost layer of ceramic to protect against contamination, and the walls of most vessels are not thick enough to support the removal of more than a few millimeters of material without risking failure.

Regardless of the how much data are gathered from increasingly smaller sherd sizes or the shrinking quantity of material removed from vessel walls, it remains that at least a portion of the object is irrevocably damaged. The pulverization of sherds or the drilling of holes may not be necessary in all cases. An experimental protocol for non-destructive residue extraction was tested on seven samples from three vessel fragments (see Table 6.6), and the lipids removed from the samples were similar in kind and amount. The non-destructive protocol actually resulted in a larger amount of total lipid extract per gram of sherd than the standard protocol in two of the samples.

Table 6.6 Description of sherds used in the non-destructive protocol.

Sample	*Protocol*	*TLE µg/ Sherd g*	*Total Peak Area*	*Decoration*	*Sherd*
LEO 01	sonication	0.3617	1.33×10^7	Meillacan	bowl body
LEO 02	standard	0.1559	1.31×10^7		
LEO 03	sonication	0.1143	1.31×10^7	Undecorated	jar rim
LEO 04	standard	0.0712	1.34×10^7		
TAM 25a	standard	0.2941	1.28×10^7	Undecorated	bowl body
TAM 25b	sonication	0.2474	1.22×10^7		
TAM 25c	solvent rinsed, then crushed	0.1688	1.24×10^7		

Rather than pulverizing the sherds to improve the efficacy of the solvent extraction, the entire sherd was quickly rinsed with dichloromethane/methanol solution (2:1 v/v) to remove any surface contaminants. It was then placed in a bath of the same solution and ultrasonicated for two episodes of 20 minutes each. The supernatant was than processed in the same way as in the standard protocol: decanted, filtered, evaporated, derivatized, and so on. The non-destructive protocol is discussed in-depth in Chapter 5.

A Student's t-test is used to evaluate the significance of the difference between the means in a population. The t-test of all lipids measured in the pair of samples analyzed by GC-MS (TAM 25a and TAM 25b) yielded a significance level 0.55, meaning there was no statistically significant difference in their composition. A qualitative analysis of the chromatograms of the other pairs confirms this result (see Figures 6.1, 6.2, and 6.3). Although there are some dissimilarities between the abundance levels of the compounds, most of the target lipids are present in each of the samples. In the pair analyzed by GC-MS, only three fatty acids and three alcohols varied in their presence by more than five percent. The remaining compounds in those classes showed nearly the same relative percentage of abundance.

While the non-destructive protocol has only been tested for a limited number of samples, it shows promise as an alternative method for the absorbed residue analysis of intact vessels or unique sherds. The technique may be easily applied to whole pots as well as fragments. The only limiting factor is the size of the ultrasonication bath tank. It is unknown if the solvents used cause any long-term damage to the integrity of the ceramic fabric, but they are commonly used chemicals that evaporate very quickly at low

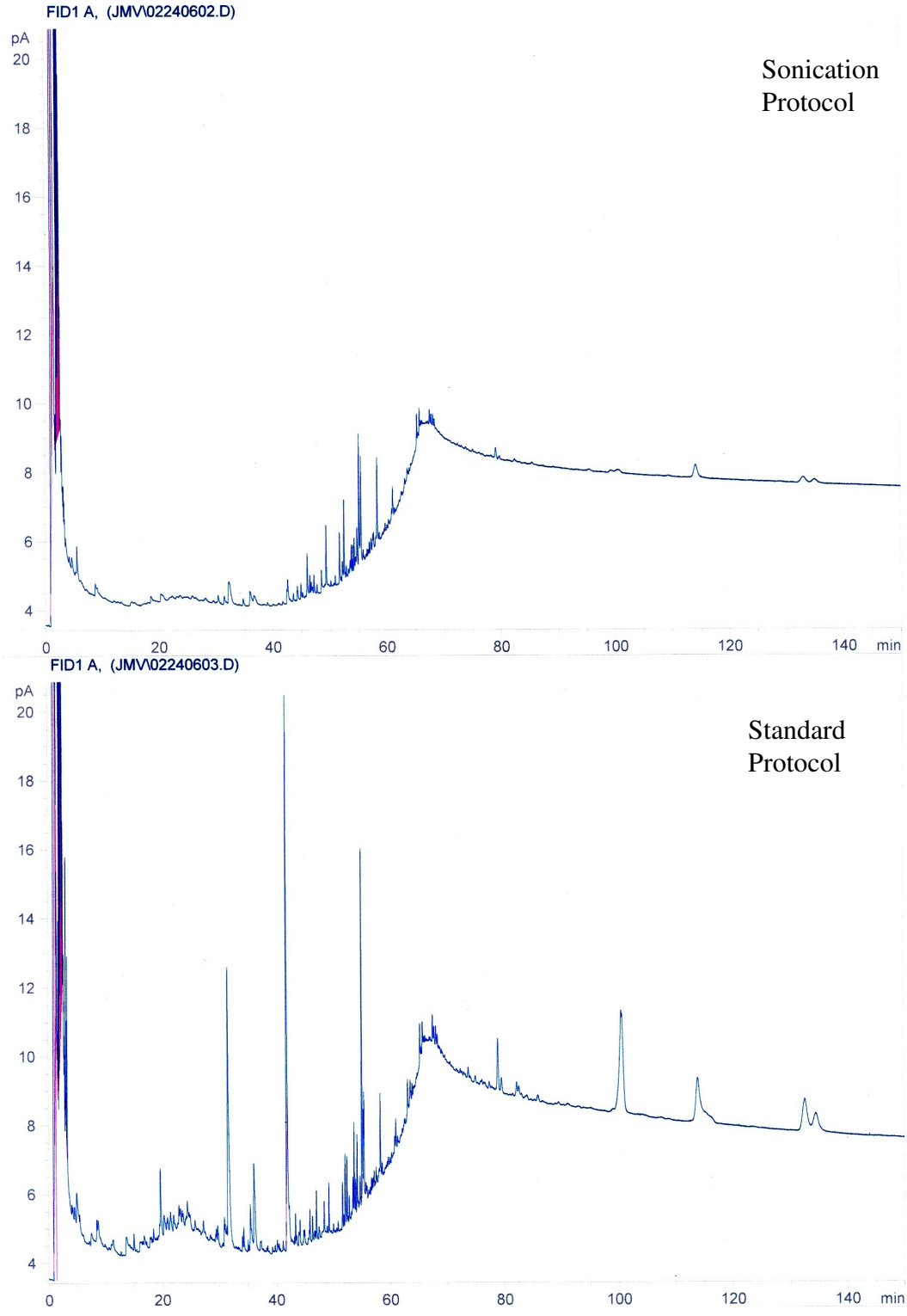


Figure 6.1 Chromatograms of LEO 01 (above) and LEO 02.

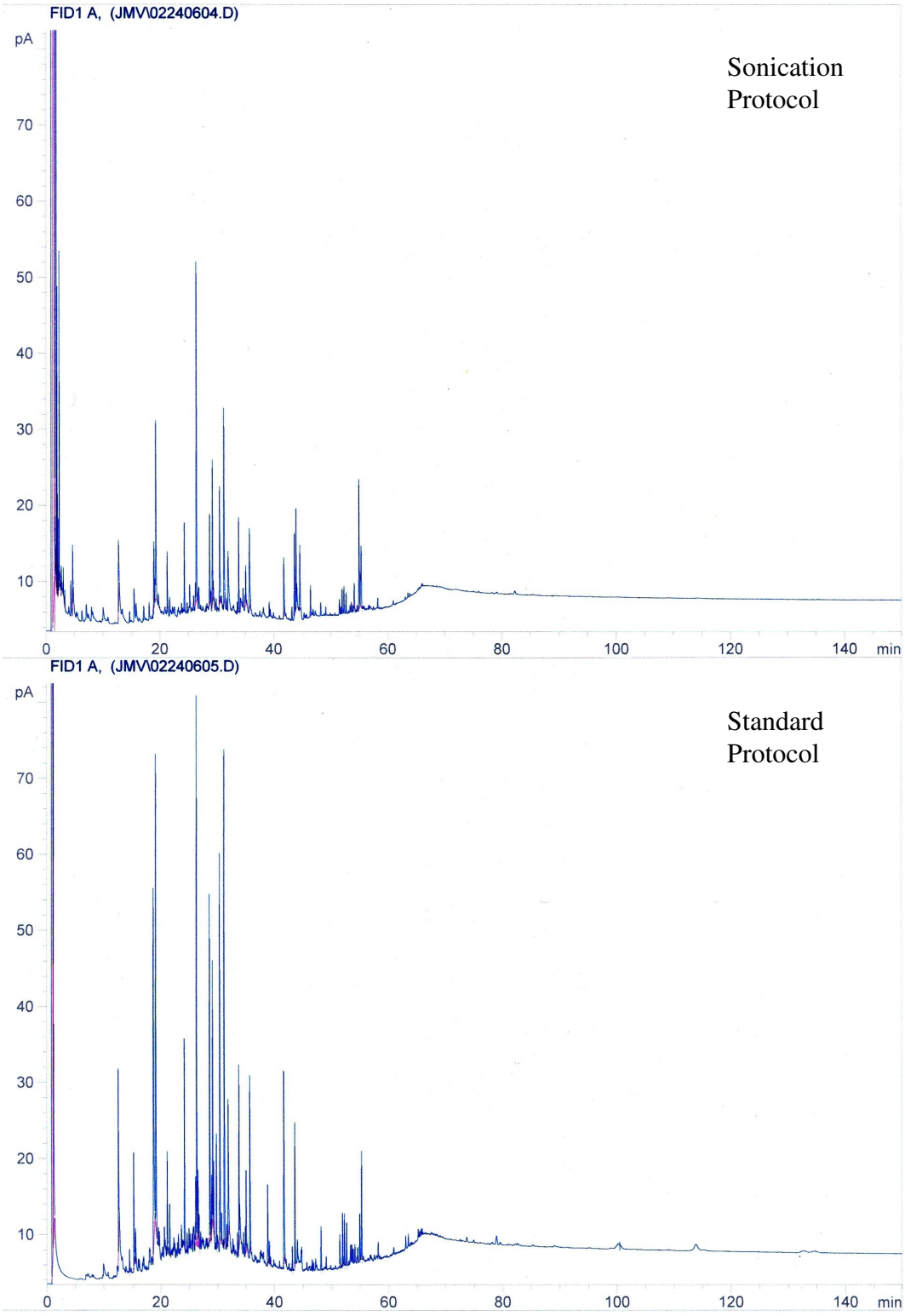


Figure 6.2 Chromatograms of LEO 03 (above) and LEO 04.

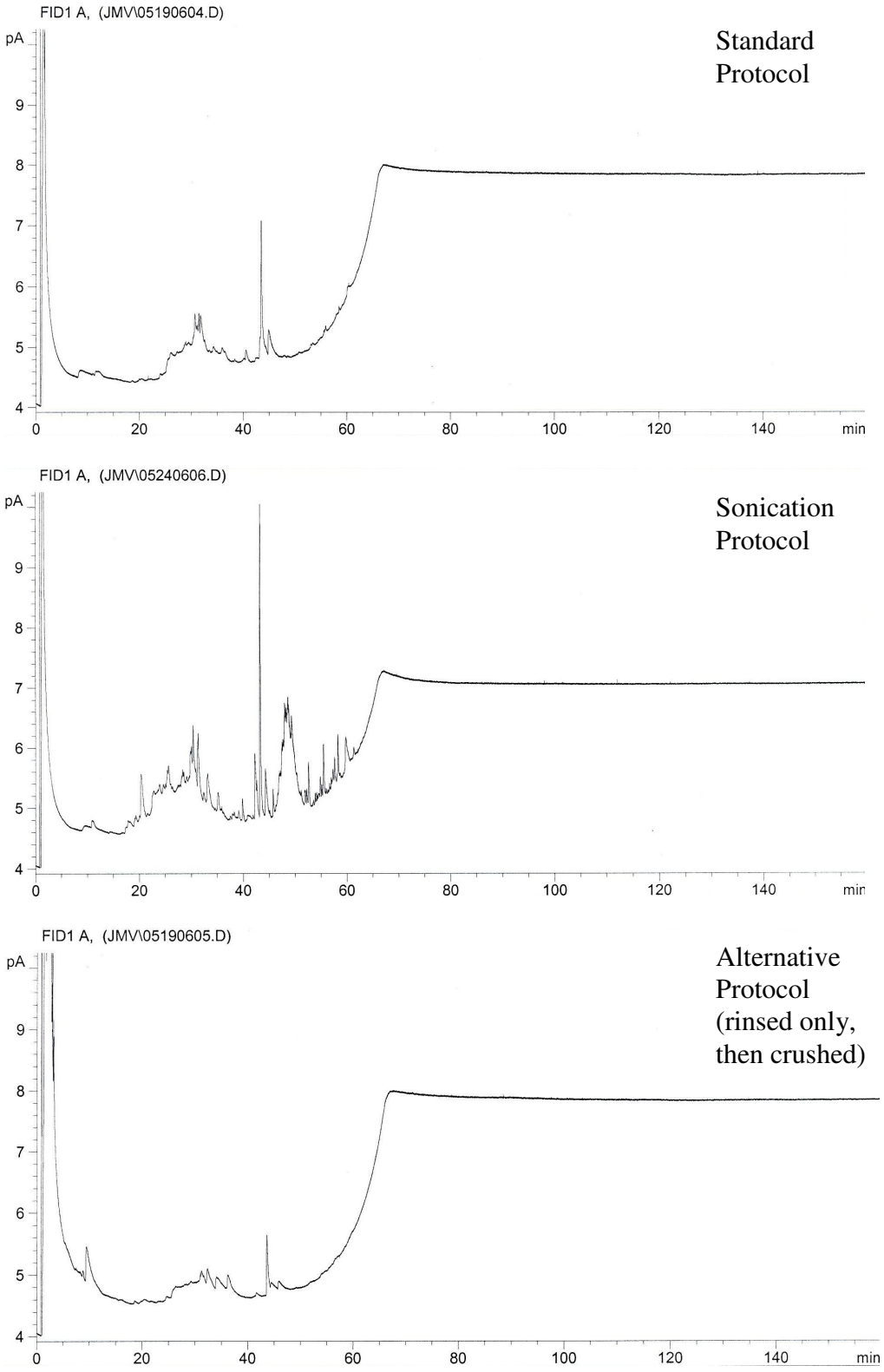


Figure 6.3 Chromatograms of TAM 25a (above), TAM 25b (middle), and TAM 25c.

temperatures and are expected to cause little to no ill effects. Still, the damage to the pottery can only be a fraction of that produced by drilling and deeply scraping vessels, to say nothing of the crushing of sherds. If further tests of this protocol continue to produce similar results, it is possible that irreplaceable artifacts, even museum-quality pieces, can be tested for organic compounds with little risk of damage. The ability to analyze unique vessels and rare sherds broadens the scope of research into dietary reconstructions and allows for comparable studies of organic compounds from non-food origins, such as ritual behaviors.

CHAPTER 7:

SITUATING SUBSISTENCE IN THE CONTEXT OF CHANGE

Introduction

Domestic ceramic vessel fragments from across Hispaniola can preserve organic material absorbed within their fabrics and protect the compounds from the environment there for several hundreds of years, at least. The lipids can then be successfully extracted in a laboratory and identified using gas chromatography-mass spectrometry (GC-MS). In the previous chapters, it was shown that there is a strong probability most of the residues originated from the contents of the vessels during their intended use rather than as contaminants absorbed after discard. Sets of soils and sherds showed differences in lipid content and abundance, suggesting the burial environment does not influence the residue within pottery. As demonstrated by control and experimental samples, post-excavation handling and storage can be managed and contaminants reduced, or at least identified.

With the various causes of contamination discounted, the source of the absorbed residues can be linked to the manner in which the vessels were utilized by people in the past. The sherds show a range of fatty acid profiles, suggesting variability in use patterns and food content. This chapter will discuss the ways in which the categories or types of food are identified and how that interpretative power varies in precision. Then the potential food sources for the samples from each site are identified and compared. In

general, it appears that the cooks using the vessels studied here prepared a diverse menu. Although it is not possible to recreate the exact dishes made within the vessels, many either held assorted ingredients at one time or were used in multiple episodes to process a single, different resource. In addition, comparisons are also made among the foods used by the people of each culture and in the different types of vessels.

Distinguishing Food Types

As mentioned in Chapter 4, there are a number of techniques used to categorize foods and even to distinguish specific plants or animals. The most unambiguous method of identification is to recognize a biomarker produced only by a certain species found in the area of study. For instance, the resin dehydroabietic acid (DHA) is associated with coniferous trees. The presence of that compound within a sherd would provide evidence that resin, tar, or other pine products were absorbed into that particular vessel. Of course, a biomarker does not differentiate among the many ways in which a compound is incorporated into the ceramic fabric. The resin may have been from boiling pine nuts, from the sealing of the vessel with tar, from the addition of pitch for its flavor, or from contamination. Each of these sources would result in the presence of DHA but all are related to very different methods of vessels use with different implications for diet. Careful consideration needs to be given to the context of the artifact, its presumed function based on shape and size, and other variables.

Many other biomarkers exist. Some sterols, such as sitosterol and stigmasterol are found primarily in plants, although small amounts are also noted in animals that eat those plants. Another sterol, cholesterol, is almost exclusively associated with animal

tissue in other absorbed residue analyses. Yet not all flora and fauna have the same compounds in the same proportions. The broad categories of "plant" and "animal" can be further subdivided. The fatty acid $C_{24:1}$ is frequently identified within marine fish but is absent or rare in freshwater species (Hildritch and Williams 1964; Morgan, et al. 1983; Patrick, et al. 1985). In the same way, there are unique compounds associated with several types of plants (e.g., Bender 1997; Smith 1970).

Most food sources do not have specific lipids with which they can be identified. Instead, less precise but more widely found compounds are usually employed to determine food categories. Although $C_{18:0}$ fatty acid is a component of prepared foods made from most species of animals, it is usually found at a low abundance. But when occurring at higher levels, especially if combined with the presence of branched acids with odd carbon numbers, the compound points to the presence of ruminant animals or their milk (Copley, Berstan, Dudd, et al. 2005; Copley, Berstan, Mukherjee, et al. 2005; Copley, Berstan, Straker, et al. 2005; Rhee 1992). The leaves of cabbages (*Brassica* sp.) have a relatively large amount of OH C_{29} alcohol (Charters, et al. 1997; Evershed, Charters, et al. 1995), and other species in the Cruciferae family (like mustard, turnip, and watercress) show elevated levels of $C_{22:1}$ (Colombini, et al. 2005; Smith 1970). Lower abundances than normal can also be a signal for food types. In mollusks, unlike most animal species, the occurrence of $C_{18:1}$ fatty acid tends to be reduced (Deal, et al. 1991). Each of these compounds is found elsewhere in nature, but their presence or absence, again when combined with the context of the artifact, can provide evidence to support a classification.

Organic compounds can degrade over time, leading to the disappearance of lipids used in identification. As a result, the fatty acid composition of a food as originally cooked may be dissimilar to that found absorbed into the vessel when recovered some time later. For example, the fatty acid $C_{18:0}$ is found in high levels only in ruminant animals (Garton, et al. 1971). Yet the presence of $C_{18:0}$ could also be related the decomposition of $C_{20:1}$, a biomarker for fish and marine animals. The latter may be replaced by the former over time (Deal 1990). Alternatively, the increase in relative abundance of $C_{18:0}$ may be a result of the more rapid degradation of $C_{20:1}$. Although such events could seriously confuse attempts at identification, a careful consideration of the archaeological context and processes of chemical change can alleviate many potential problems.

Researchers have studied the rates at which compounds decompose over time and have offered calculations to account for the expected changes. Ratios of certain fatty acids or fatty acid groups are a common solution to the problem of degradation (Marchbanks 1989; Skibo 1992; Skibo and Deal 1995). For example, sherds associated with the cooking of meat are typically higher in $C_{12:0}$ and $C_{14:0}$ fatty acids relative to $C_{20:0}$ and $C_{22:0}$, whereas those that processed plants nearly always have larger percentages of the longer chain fatty acids. The residue fish leave in vessels shows a relative abundance of fatty acids with an odd carbon number when compared to the rest of the compounds present. By using ratios, even though the absolute value of a lipid may decrease, its quantity relative to similarly effected compounds remains the same. Archaeological samples of varying ages and from disparate environments can then be compared with some confidence in the results.

This research uses all of the above evaluative techniques to interpret the results of the GC-MS analysis. When available, biomarkers signal the existence of individual foods, but the application of ratios also aids in reconstructing the types of resources processed in each vessel. Sets of criteria for residue identification from several previous studies are used here (see Appendix D), resulting in a variety of exploited foodstuffs. Some of the potential classifications are conflicting, where one set of lipids extracted from a sherd suggests meat while other compounds from the same sample can only be the result of plants. Others seemed to be contradictory to the context from which the vessel was recovered. In more than one indigenous sample, for instance, there was evidence of ruminant animal fat, such as that from cattle, goats, or sheep, even though the sherds may be from a period prior to the 15th century. Yet by evaluating the source or sources of residue with as many possible formulae and criteria, a broad scope of potential foods can be identified.

The use of a variety of decisive factors may lead to some confusion, but it serves as a good test of the predictive powers of previous research. There are limitations to absorbed residue analysis and many were encountered in this study, especially in terms of uncertainty with regards to the precision of its powers of identification. These concerns are discussed in the next chapter. Still, this research provides a start to the investigation of West Indian foods as produced by Taíno and colonial European cooks. A large body of data relating to the contents of cooking vessels used in the area was produced. Using the categorization of resource types, a depiction can be made of the overall diet of the people of the contact-period Caribbean.

Descriptions of Residues from Sites

The 55 samples analyzed using GC-MS were obtained from a total of seven sites. The possible foods processed at each are discussed below. While there may be a lengthy list of potential sources for the residues absorbed into each sherd, by assessing their context with regard to site location and the other sherds present, the most likely food or foods associated with each sherd may be determined. In most cases, the vessel probably contained more than one type of ingredient during its useful life. This appears to be true regardless of vessel form or the culture of the cook who handled it.

Cangrejera Oeste

Only one sherd (CO 01) was analyzed from Cangrejera Oeste, a site on the shore of the Caribbean Sea in the southeast region of the island (see Figure 7.1). The sherd was excavated from an area with very sandy soil and disturbed by resort construction. It is possible that these factors are the reason CO 01 had no fatty acids or alcohols present, but it could also be that the sherd was from a burén, the thick ceramic griddle on which casabe, the bread made of cassava flour, was grilled. Cooking using indirect heat and no liquid would not be a method in which lipid residues would be easily absorbed into the fabric of the vessel. Cholesterol and squalene were noted from the sample, however, and the presence of these two compounds together suggests contamination through handling.

Edilio Cruz

Edilio Cruz is a working cattle ranch, cleared of most trees, inland from the Atlantic Ocean on the north coast of the island (see Figure 7.1). Of the five sherds

Figure 7.1 Archaeological sites used in GC-MS analysis.

collected from the surface of the site of Edilio Cruz, four had fatty acids present at levels with which source determination could be made. See the charts in Figure 7.2 for the relative abundances of fatty acids and the possible sources for each sample's residue.

Although the residue from the remaining sherd (ECZ 02) could not be categorized using fatty acids, it had an abundance of long-chain alcohols (OH C_{20} and greater) which is a biomarker for plants (Reber and Evershed 2004). It also yielded triacylglycerols (TAGs), lipids used by most animals as well as oil-bearing seed plants to store energy for intermittent and specialized usage (Gurr, et al. 2002). The most likely native faunal sources of TAGs in the West Indies are fish. The larger animals brought by the Europeans would also result in TAG residues when cooked. The combination of TAGs and long-chain alcohols in ECZ 02, which came from a bowl, suggests either a mix of plant and fish oils or an oil-bearing seed plant alone.

The remaining samples were from a vessel of undetermined shape (ECZ 05), two jars (ECZ 11 and ECZ 13), and soil collected from the site (ECZ 15). The soil produced a pattern associated with nearly all possible food types, from mollusk to land mammal to plant. This is to be expected due to the current use of the site. The sample was taken from the ground surface where land crabs, cow manure, and pasture grasses were also present. The soil likely contained traces of all these materials and more.

The vessel from which ECZ 11 was taken exhibits evidence for a mixed use of land mammal tissue and plant material. This is similar to ECZ 13, which included residue from land mammals and seeds or seed oil. The interpretation is based on the low amount of long-chained alcohols, the presence of cholesterol, and the various fatty acid ratios in both samples. The land mammals present in all the indigenous sherds were

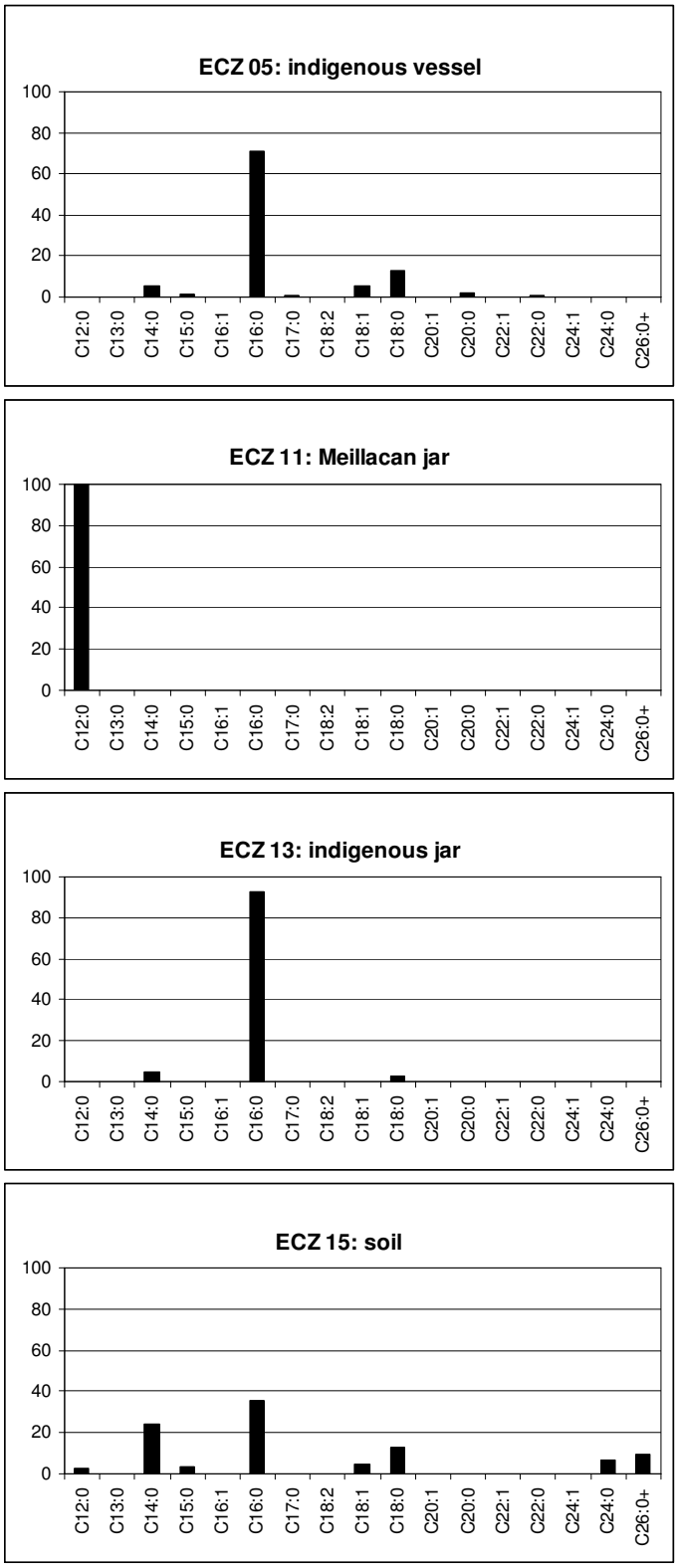


Figure 7.2 Relative abundances of fatty acids in residues from Edilio Cruz.

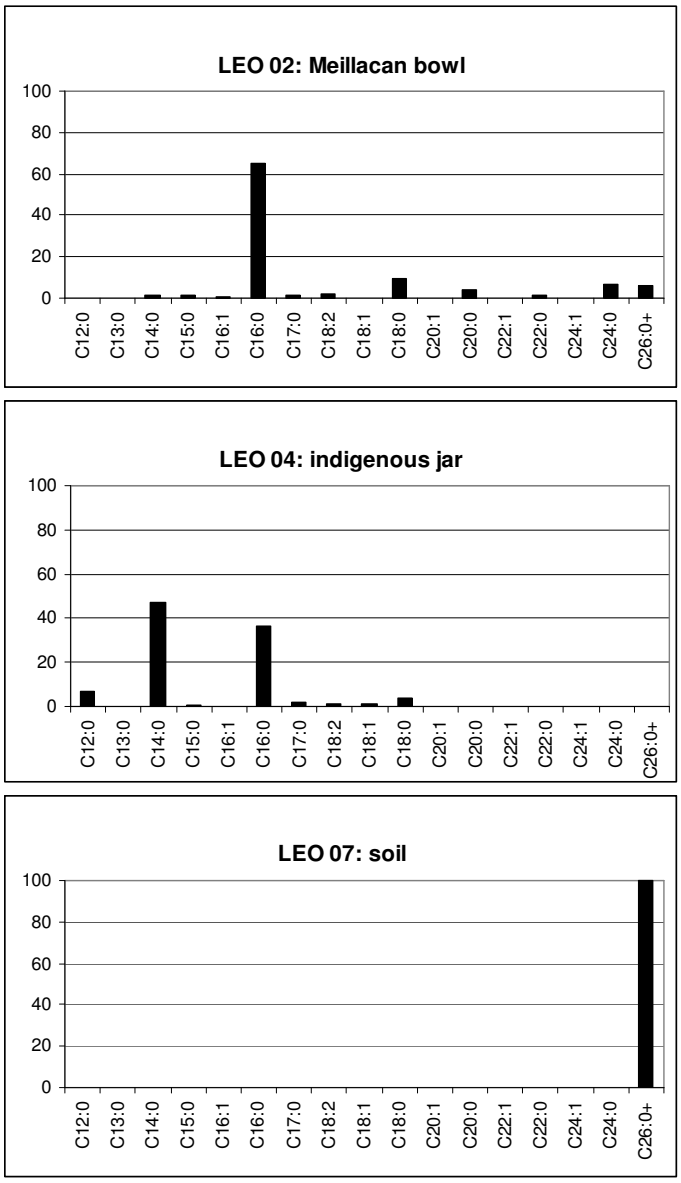
almost undoubtedly the hutias, small rodents common to the island around the time of contact, or dogs. The undetermined vessel had also been used to process land mammal and plant substances, but in addition there were compounds linked with fish and a low presence of $C_{18:1}$ fatty acid commonly associated with mollusks.

Loma de Leonardo

The site of Loma de Leonardo is on the top of a ridge with a view of El Tamarindo and the Atlantic Ocean. Two sherds and one soil sample were selected from a wealth of ceramic material visible on the surface of the site, and all yielded clear chromatograms for analysis (see Figure 7.3). The lipids from the soil (LEO 07) were exclusively associated with plant matter, with a prevalence of long-chain fatty acids and alcohols. The sherds were from a bowl (LEO 02) and a jar (LEO 04). Both showed a mixture of compounds common to fish, plants, and roots. If the root used was cassava, this points to Taíno cooks exploiting their staple crop for more than just bread. The fatty acid 18:1 contained within LEO 04 was in the range signifying a presence of mollusk.

El Perenal

Three sherds were collected from the surface of El Perenal, a site immediately adjacent to El Tamarindo or possibly the other half of a very large site comprised of the two (see Figure 7.1). They were from two bowls (PER 02 and PER 05) and a jar (PER 03). No fatty acids or alcohols were found in the residue of PER 05, and therefore no identification of possible contents was possible. While there was cholesterol present in



Possible source:
Greens
Fish
Root

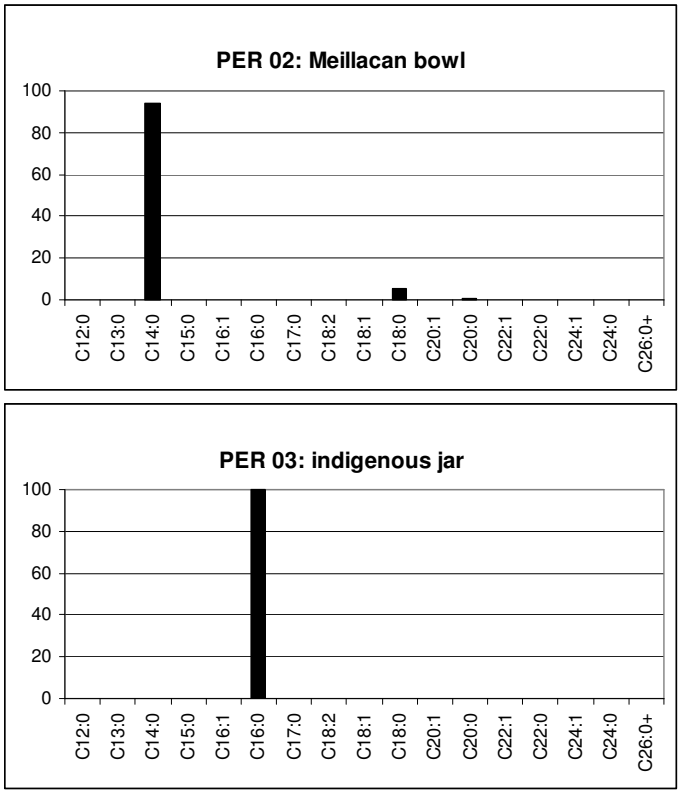
Possible sources:
Fish
Greens
Mollusk
Root

Possible source:
Greens

Figure 7.3 Relative abundances of fatty acids in residues from Loma de Leonardo.

the GC-MS analysis, there was also a quantity of squalene. The co-occurrence of these compounds suggests post-excavation contamination.

The remaining vessels also contained cholesterol, but they possessed additional evidence that they were used to process meats (see Figure 7.4). Various fatty acid ratios from PER 02 imply the bowl at one time held meat from land mammals and seeds or seed oils. Fish oils, on the other hand, were in contact with the walls of the jar from which PER 03 was taken. The abundance of TAGs and lack of long-chain fatty acids typical of plant material support this claim.



Possible sources:
Mammal
Seed

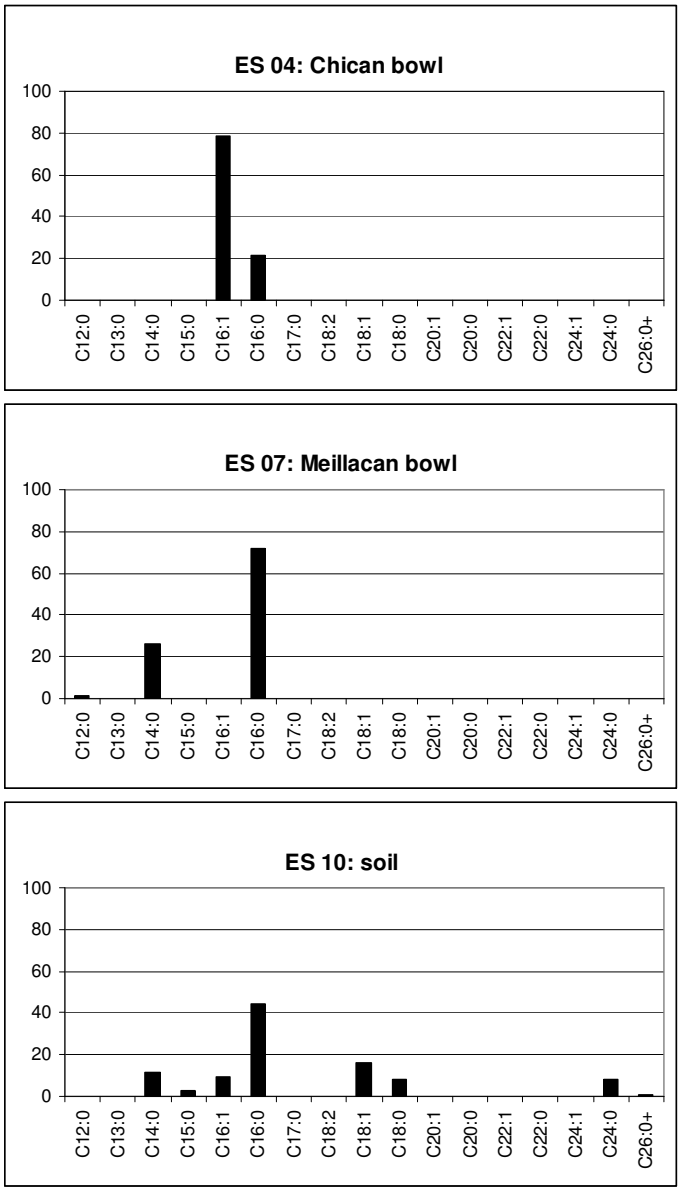
Possible source:
Mammal

Figure 7.4 Relative abundances of fatty acids in residues from El Perenal.

Punta Rucia

The context for the material from Punta Rucia (sherds from four bowls and two samples of soils taken from the sherds) is unique to this research. The vessel fragments were recovered together with two human burials, possibly found in a cave further west along the Atlantic shore (see Figure 7.1). The Taíno would sometimes bury their dead with grave goods, including food to sustain them in the afterlife (García Arévalo 1992). It is possible, then, that these sherds are from vessels used to hold material thought to be important to the interred individuals. Interestingly, two of the four sherds (ES 02 and ES 06) contained no fatty acids. The residue from both of these sherds, however, exhibited moderate levels of long-chain alcohols and TAGs. One (ES 06) contained DHA as well. It is likely that they once held plant material in some form, but probably not cooked in the same manner as that of the majority of the samples in this study. The DHA may have come from incense or copal, an aromatic resin sometimes used for its fragrant smoke. Whether the vessels were made specifically for the burials or were used prior to their deposition with the bodies is unknown. One of the soil samples (ES 09) also had no fatty acids, nor was there a presence of alcohol. Based on the lack of diagnostic residues, no interpretation of the soil contents can be made at this time. The other two bowls produced limited chromatograms. Nevertheless, there was enough material to categorize the residue (see Figure 7.5).

The source of food from one vessel (ES 04) has a similar $C_{16:1}$ abundance as that found in other residues classified as coming from the processing of marine animals. The other sherd (ES 07) appears to be a land mammal, possibly mixed with fish and plant greens, based on numerous ratios of fatty acids. Contents of the soil removed from these



Possible source:
Fish

Possible sources:
Fish
Greens
Mammal

Possible sources:
Greens
Fish
Mollusk

Figure 7.5 Relative abundances of fatty acids in residues from Punta Rucia.

sherds (ES 10) provide evidence for many of the possible identified sources: fish, mollusk, and plant material. Yet, the remains of fatty acids related to mammals did not appear as they did in one of the sherds from which the soil was taken. Moreover, the soil had evidence of mollusks, while the sherds did not. The fact that the soil samples recovered from material excavated at this site either had no fatty acids or alcohols, as in the case of ES 09, or had fatty acids in a substantially different ratio than those found in the sherds further confirms that the burial environment does not contribute to the residue within the artifacts.

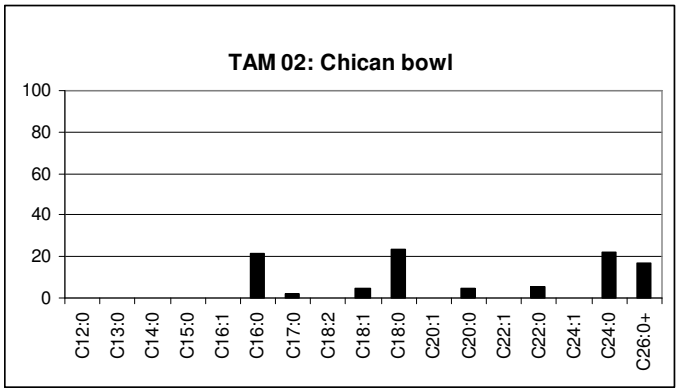
El Tamarindo

Samples from El Tamarindo, a ridge-top village site near Río Bajabonico and La Isabela (see Figure 7.1) all exhibit levels of fatty acids, alcohols, and other lipids sufficient for characterization. This fact may relate to the collection method of the material. Except for the experimental sample (TAM 30) discussed in depth in Chapter 6 and not considered any further here, all the samples were freshly excavated during a systematic investigation of the site. The research design in place during the excavation included the selection of sherds with the potential to contain extractable residue. In most cases, the sherds were identified *in situ,* wrapped and recorded, and then placed directly into designated bags. The artifacts were not washed or processed any further until their arrival at the laboratory.

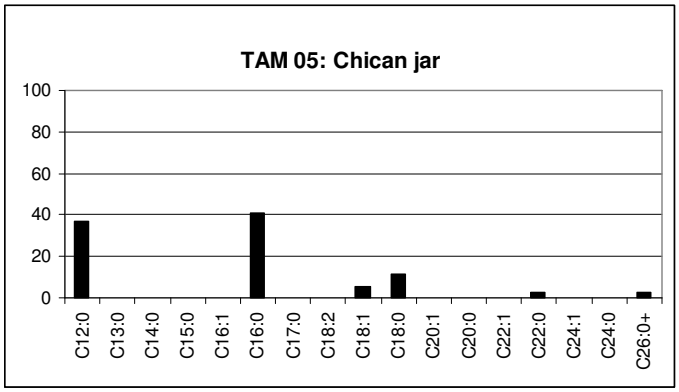
The El Tamarindo samples are comprised of 18 indigenous sherds, two charcoal samples taken from sherds, and a soil sample collected at the site. Two of the sherds were processed as two samples each. One was a burén split into top and bottom portions

(TAM 18a and TAM 18b, respectively), and the other was scored and broken so that extraction techniques could be compared (TAM 25a by standard protocol and TAM 25b by the non-destructive sonication method). More than half of the sherds are decorated: six are Chican and four are Meillacan in design. They come from bowls, the aforementioned burén, jars, and other vessels of unknown form. All contained residue with strong chromatographic peaks (see Figure 7.6). The compounds noted in those peaks were varied in their origin, ranging from the common and general classes of roots and fish to the rare and specific categorizations of species related to the Brassicaceae family of plants (cabbage, mustard, and turnip) and ruminant animals.

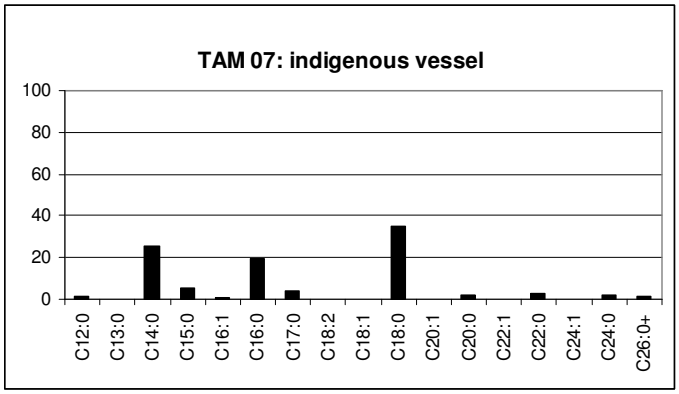
The latter assignments are of special interest. Ruminant animals, like cattle, goats, and sheep, make efficient use of grasses by chewing a cud of regurgitated, partially digested food. Bacterial synthesis in the gut produces a relatively high abundance of branched-chain fatty acids distinctive to this type of herbivore (Christie 1978, 1981). There is, then, a correlation between the ratio of $C_{17:0}$ (branched-chain) to $C_{18:0}$ fatty acids and the identification of ruminant tissue via isotopic analysis (Dudd, et al. 1999). Another ratio of $C_{15:0}$ and $C_{17:0}$ to $C_{12:0}$, $C_{14:0}$, $C_{16:0}$, and $C_{18:0}$ fatty acids (Reber 2001) and the biomarker of high levels of $C_{18:0}$ (Deal 1990) further confirms this classification. These criteria were used to identify residues from ten samples excavated at El Tamarindo as being derived in part from ruminant animals, even though no such species were indigenous to the Caribbean around the time of contact with Europeans.



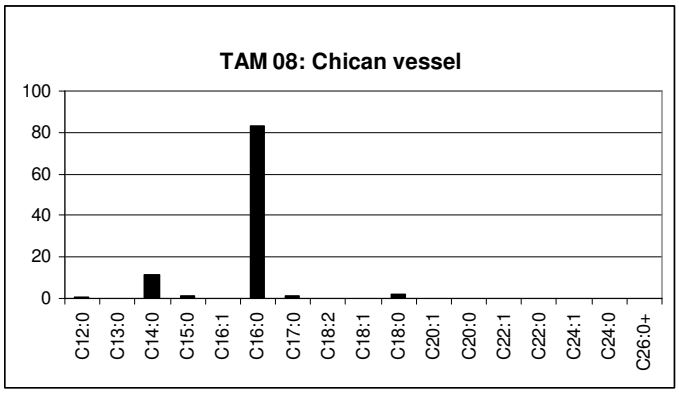
Possible sources:
Fish
Greens
Mammal
Mollusk



Possible sources:
Fish
Greens
Mammal
Mollusk

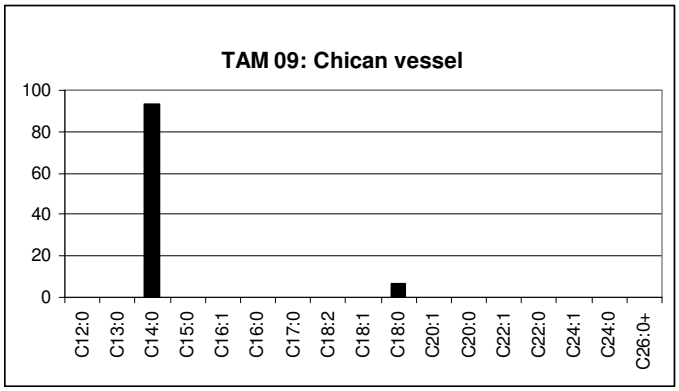


Possible sources:
Fish
Greens
Mammal
Ruminant

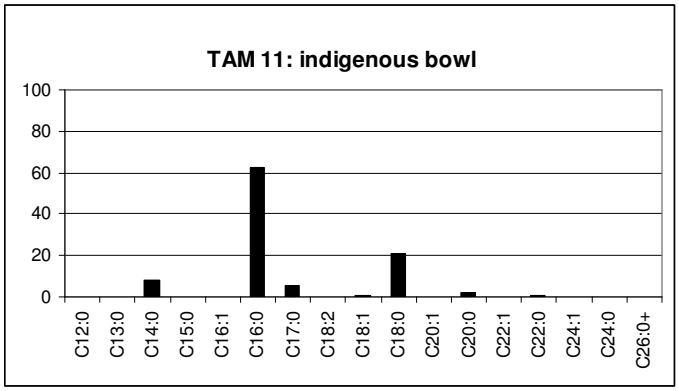


Possible sources:
Greens
Mammal

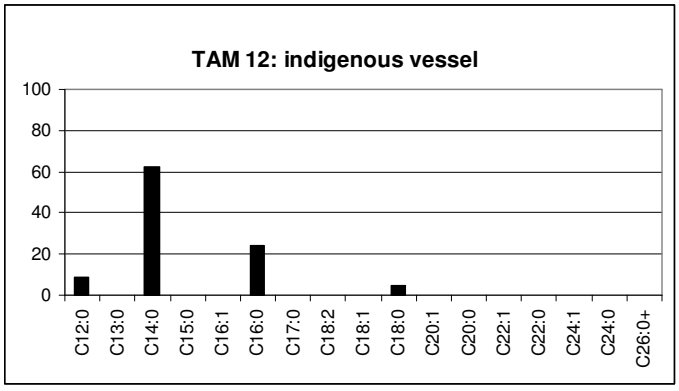
Figure 7.6 Relative abundances of fatty acids in residues from El Tamarindo.



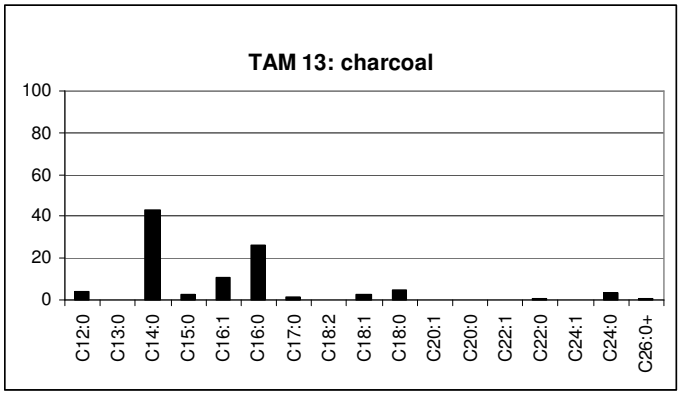
Possible sources:
Greens
Mammal
Seed



Possible sources:
Fish
Mammal
Mollusk
Ruminant
Seed

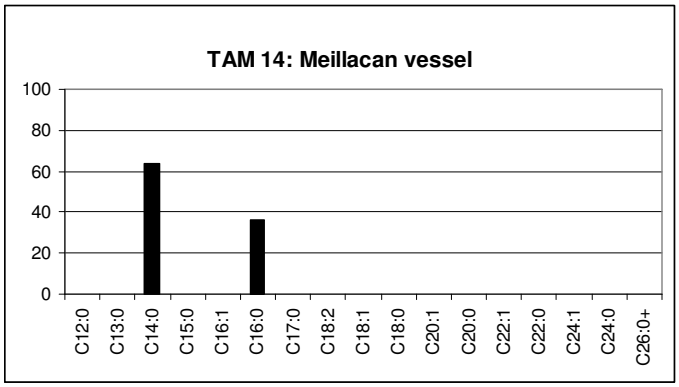


Possible sources:
Mammal
Seed

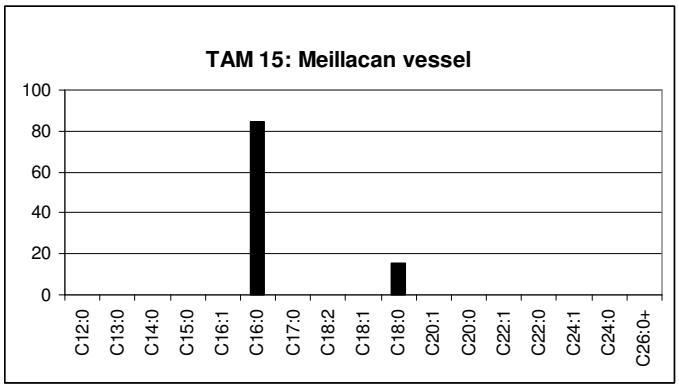


Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant

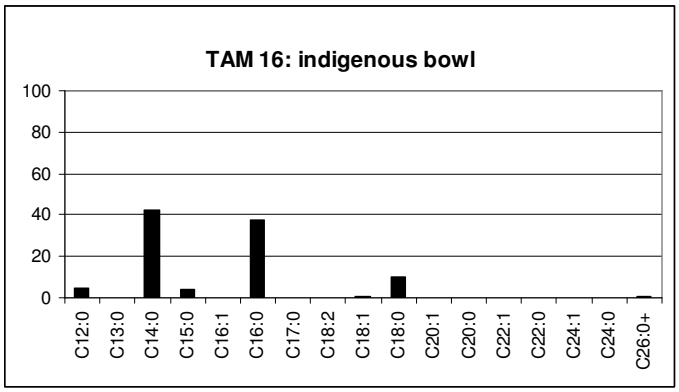
Figure 7.6 Relative abundances of fatty acids in residues from El Tamarindo (cont'd).



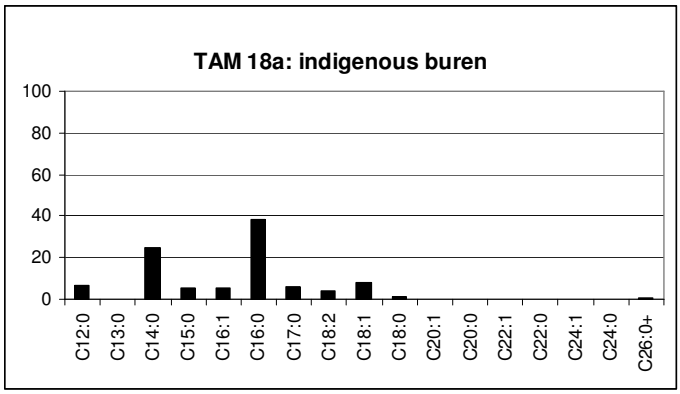
Possible sources:
Greens
Mammal



Possible sources:
Greens
Mammal

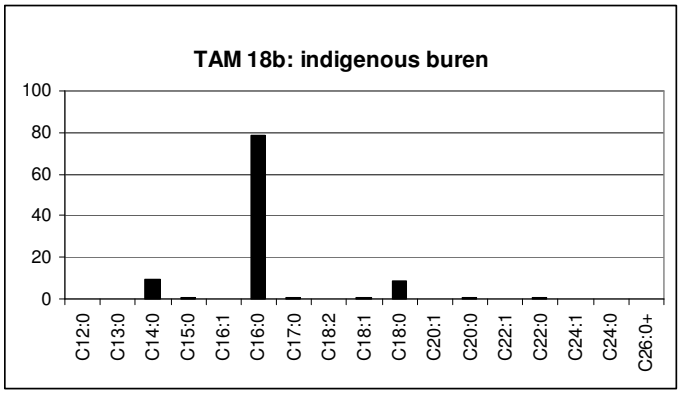


Possible sources:
Greens
Mammal
Mollusk
Seed

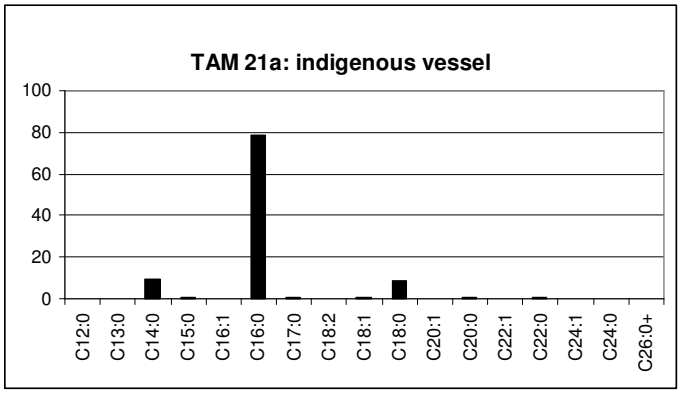


Possible sources:
Fish
Greens
Mollusk
Root

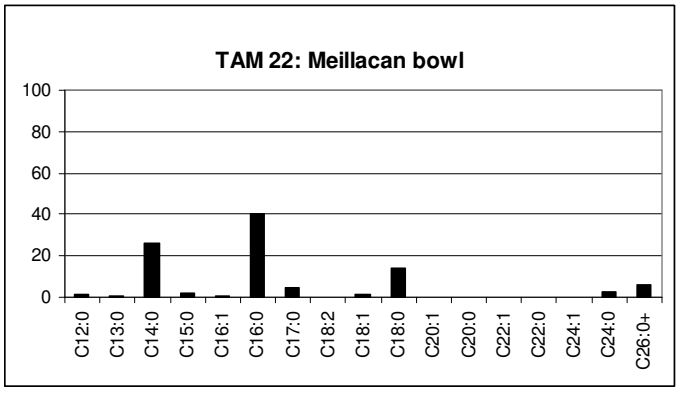
Figure 7.6 Relative abundances of fatty acids in residues from El Tamarindo (cont'd).



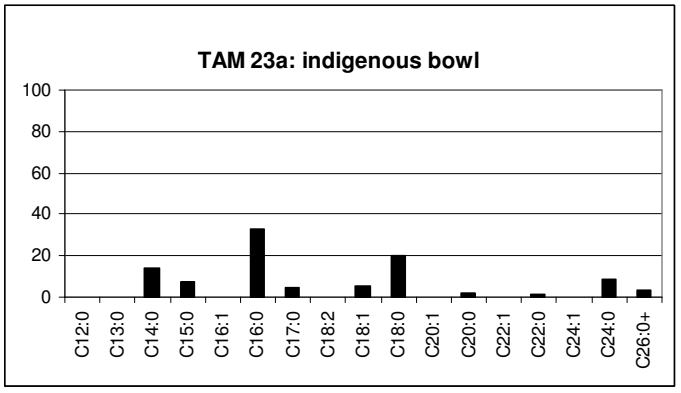
Possible sources:
Fish
Greens
Root



Possible sources:
Fish
Mollusk
Seed

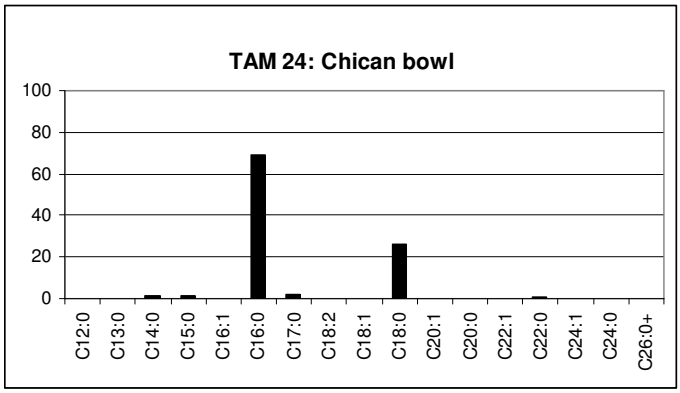


Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant

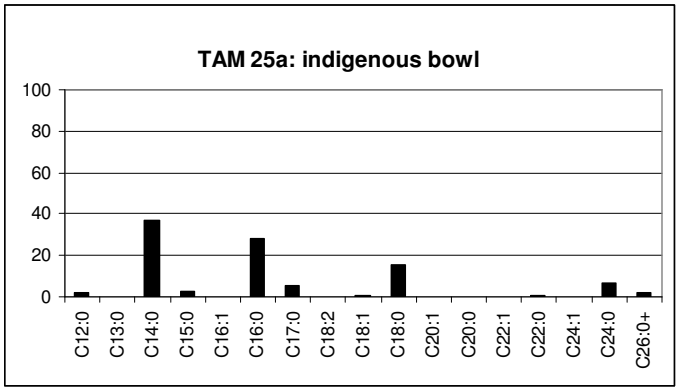


Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant

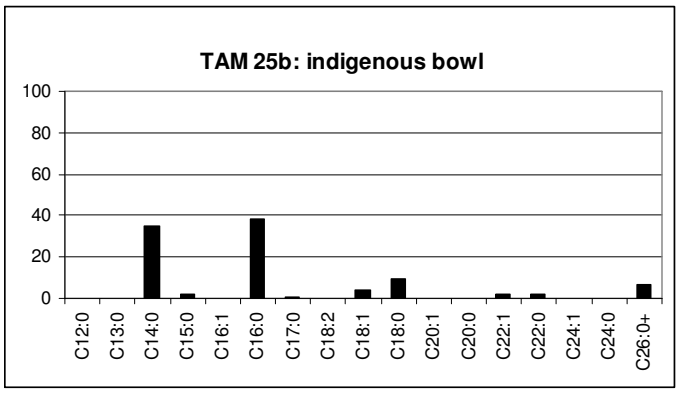
Figure 7.6 Relative abundances of fatty acids in residues from El Tamarindo (cont'd).



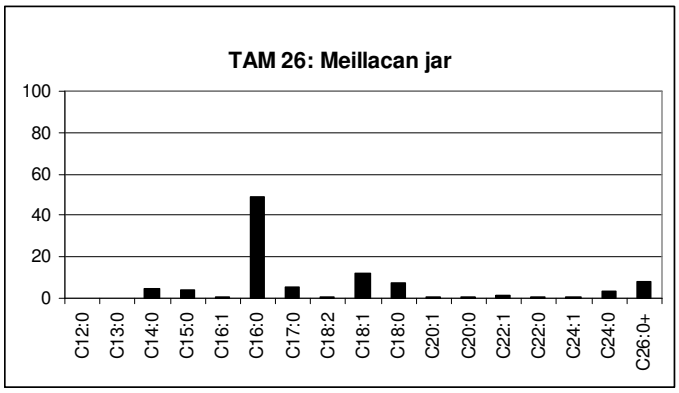
Possible sources:
Greens
Mammal
Seed



Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant

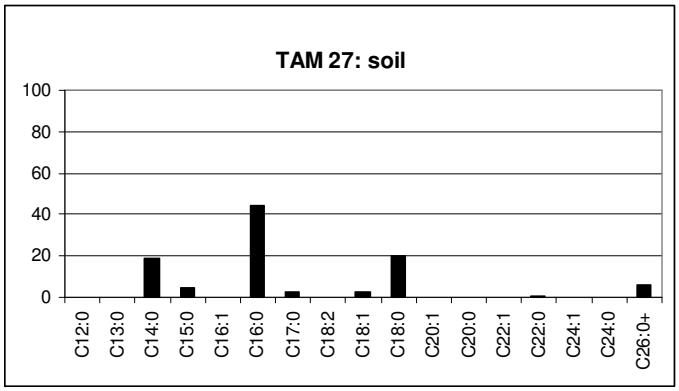


Possible sources:
Fish
Greens
Mammal
Mollusk

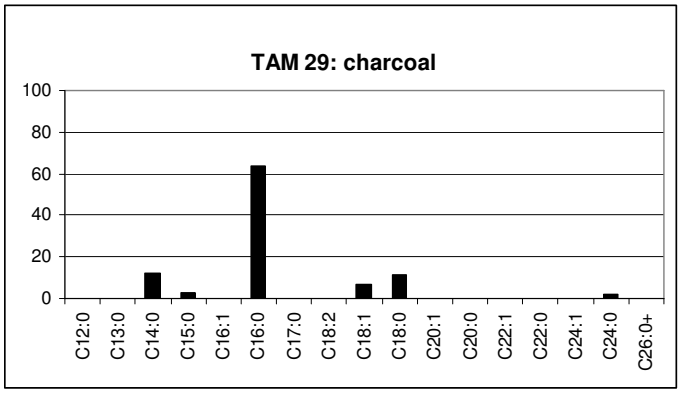


Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant

Figure 7.6 Relative abundances of fatty acids in residues from El Tamarindo (cont'd).



Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant



Possible sources:
Fish
Greens
Mammal
Mollusk

Figure 7.6 Relative abundances of fatty acids in residues from El Tamarindo (cont'd).

The ruminant-containing samples were five bowls (TAM 02, TAM 11, TAM 22, TAM 23a, and TAM 25a), one jar (TAM 26), one burén (TAM 18a), one vessel of undetermined form (TAM 07), one charcoal sample (TAM 13 taken from TAM 12), and the soil sample (TAM 27). The primary component of the residues from these samples was typically plant greens (n=8), but they also included mixes of fish, mollusks, roots, and seeds or seed oils. All the sample were classified as having a ruminant animal presence based on possessing the biomarkers or exceeding the ratio values of at least two of the criteria mentioned above, as a confirmation of this unexpected result.

There are three explanations which would account for the presence of ruminant animal tissue or milk in indigenous vessels. The artifacts may all date to after 1494 and the Taíno used them to cook or otherwise process foodstuffs obtained, directly or indirectly, from the Europeans. Self-sufficient Castilian range cattle eventually thrived on the island because of their ability to find forage and withstand long walks between sources of water (Bennett and Hoffmann 1991). Goats and sheep likewise adapted, although not as successfully. There is little reason for the Taíno to shift their substance base soon after contact, however, as they acquired plentiful protein resources from the sea and had established conucos already yielding crops with which they were familiar.

If the ruminant was slaughtered and tried for the sake of curiosity or novelty, its appearance would not be so prevalent in the small study sample. Perhaps the artifacts are from after the initial encounter with the Europeans. The site of El Tamarindo may have been used by Taino fleeing from the encomienda system. The indigenous society and subsistence patterns were severely disrupted at this time, and cattle that had gone feral or were taken from European ranches would have served as an available food.

The ruminant residue could also be caused by the cooking animals not native to the West Indies, but from other regions in the Western Hemisphere. Large herbivores like llamas from South America, deer from North and Central America, and moose from North America are all ruminants and are known to be used by the local people of those areas. It is possible, but unlikely, that the Taino traded for ruminant meat with people living on the mainland coasts. Although the Taíno made voyages across the Caribbean (Wilson 1997a), spoiling meat would not make for a pleasant trip.

An even less probable explanation could be that the residue was from a quasi-ruminant indigenous to the islands. Sloths have a chambered stomach and, although they do not chew cud like true ruminants, they do break down cellulose via bacterial synthesis. It is therefore a possibility that the lipid signature derived from sloth meat is similar to that of cattle. Sloths are claimed to have been found in association with human artifacts in the Dominican Republic, but they are thought to have become extinct by the time of the Taíno (White and MacPhee 2001).

It is unlikely the sherds absorbed ruminant residue through contamination with the soil. The rarity of such an occurrence has been established previously in other studies and in this chapter as well as Chapter 6. Further, the genuineness of the ruminant appearance is supported by the use of additional criteria to make the identification. The susceptibility of $C_{18:0}$ to influences of decomposition are thought to be similar to that of $C_{17:0}$ because of their comparable molecular weights and structures (Dudd, et al. 1999), and thus that ratio was utilized along with the abundance of branched odd-chained fatty acids.

Plants from the Brassicaceae family are another non-native species identified in the residue of El Tamarindo vessels. Two sherds, a bowl (TAM 25b) and a jar (TAM 26) had high levels of $C_{22:1}$, a biomarker for the species of plants related to cabbage, mustard, and turnips (Charters, et al. 1997; Deal, et al. 1991). Yet the only known domesticated indigenous Brassicaceae species in the Americas was *Lepidium meyenii* (Hermann and Heller 1997). Also known as *maca*, this radish-like plant was grown by the Inca in the Andes and found nowhere else.

The Taíno may have traded with people on the coast of South America who in turn traded with people who traded down the line with the Inca, but this is a long trip for fresh maca to make. They may have obtained cabbages from the Europeans in the same manner as they did ruminant animals. Or the residue could be associated with other plants aside from Brassicaceae. Native to the Caribbean and Central and South America are a number of species of the genus Nasturtium. These herbaceous plants have a flower that tastes similar to that of watercress, a true Brassicaceae. The nasturtium plants may be those referred to by the Spanish chronicler Oviedo as "wild cress, which in taste is precisely like that here in Spain…[but] the stems are thicker and the leaves larger" (1959: 97). The oil they produce is also comparable to that of watercress. In addition, a few species (e.g., *Tropaeolum tuberosum*) produce an edible tuber that is a major food source in parts of the Andes. Nasturtium use by the Taíno is not known at this time, but further research into the residues left behind by these plants would aid in possibly reconstructing another part of the indigenous West Indian diet.

The Brassicaceae sherds also contained residue from other plant greens, fish, and mollusks. One of them (TAM 26) is among the sherds used in the cooking of ruminant or ruminant-like animal tissue, as well. The vessel from which TAM 26 was taken, a Meillacan jar, is therefore an important link between Taíno and European cultures. It is an indigenous pot found in a local village site with two types of foreign cuisine cooked within it.

The samples from El Tamarindo that have not been discussed as yet have residues resulting from a variety of food ingredients. One bowl (TAM 10) and three vessels of unknown type (TAM 08, TAM 14, and TAM 15) were used to cook a mixture of plant

greens and meat from land mammals. A jar (TAM 05) served to hold greens, mammal meat, and fish. The same ingredients were processed on a burén (TAM 18b), with the additional residue provided by a root crop. The other portion of the burén (TAM 18a) was mentioned previously in the discussion of ruminant residue. It also has the compounds found from greens and roots.

The presence of materials from a burén other than that of cassava root was unanticipated. These forms are nothing more than very thick circular slabs of fired clay, with very large inclusions in the ceramic fabric to protect against damage from thermal shock. They were supposedly placed on the coals of a fire and radiated heat evenly to the casabe bread cooked on the top surface, much like a pizza stone. Unlike their modern-day counterpart however, the burén was thought to have been used to cook only the bread and no toppings. The additional residues from a variety of ingredients call this reconstruction into question. Pizza stones are not greased to aid in the release of the crust after cooking. Instead, the dough forms an outer layer that can be easily peeled off with a paddle. One would think casabe may be formed in the same way. It is possible, though, that the casabe dough was too moist and needed insurance against sticking that was provided by plant or fish oil.

Perhaps the oil was added as a flavor enhancement during the cooking process, or other ingredients were used to spice the casabe or augment the flour. An early anthropologist of the Caribbean, J.W. Fewkes, reports that when cassava is in short supply, "its bulk is sometimes increased by mixing the chopped leaves of the cassava plant, or the pounded seed of the mora tree (*Mora excelsa*), or of the greenheart tree (*Nectandra rodioei*), or even pounded rotten wood, with the meal" (1907: 53). This

would account both for the presence of substances other than roots alone, and also ties into the idea of El Tamarindo being occupied during the lean years following the arrival of the Europeans.

Seeds appeared to be used more by the Taíno than originally thought. The category "seed" also includes nuts and berries, which serve the same function in the plant and thus have nearly identical component compounds, as well as their oils. In addition to the samples already mentioned as also containing ruminant animals, seeds were combined with fish in one unknown vessel form (TAM 21a), with meat from land mammals in another (TAM 12), with mammals and plant greens in one bowl (TAM 24), and with mammals, plants, and mollusks in a second (TAM 16). There are a variety of seeds, berries, and nuts that could have been used. The primary seed-producing plants were used by the Taíno were Lamb's-quarters (*Chenopodium ambrosoides*) and sedge (*Cyperus* sp.). Other seeds may have come from chilies (*Capsicum* sp.), prickly pears (*Opuntia* sp.), and a number of spices. Refer to Table 2.1 for a more complete list. Still more sources may have been non-food plant seeds used for medicinal, ritual, or cosmetic purposes.

The final sample from El Tamarindo to be considered is one of the charcoal residues (TAM 048). The primary components were identified via GC-MS analysis as plant greens, fish, and mollusks. Unlike most of the samples in this research, the charcoal residues are found adhering to the surface of the sherd and not absorbed within its fabric. The efficacy of studying carbonized material is still debated by researchers in the field. The high temperatures that produce charred material may degrade their lipids so far as to be unrecognizable or lead to misinterpretations (Hill and Evans 1989).

Nevertheless, the residue from TAM 29 matches exactly that of the sherd (TAM 25b) from which it was removed, with the exception of the specific Brassicaceae component.

Las Coles

Las Coles was the satellite European settlement, where most of the settlers lived and worked. It was situated below the administrative and religious quarter of La Isabela in a flood plain of the Río Bajabonico (see Figure 7.1). Two jars and one vessel of unknown shape were analyzed for food residue (see Figure 7.7). One jar (ISA 04) had no fatty acids absorbed into its walls, but the amount of long-chain alcohols indicates a plant origin for the contents it once held. The other jar (ISA 11) contained traces of cholesterol and fatty acids in the range suggesting meat, as well as long-chain fatty acids that are associated with plants. It seems likely that this vessel was used to cook a mixture of flora and fauna. The undetermined vessel (ISA 10) showed considerable evidence for use in processing land mammals, possibly ruminants, combined with residue from fish and plant greens.

La Isabela

A total of 10 sherds were collected from the previous excavations of La Isabela (see Figure 7.1). Of these, one (ISA 12) was used as a control sherd, or blank, and another was of indigenous origin (ISA 16). As discussed in the previous chapter, all of the sherds from the European settlements were permeated by DHA, except for the blank. The rest of the compounds identified in the residues were a little more varied in their distribution (see Figure 7.8).

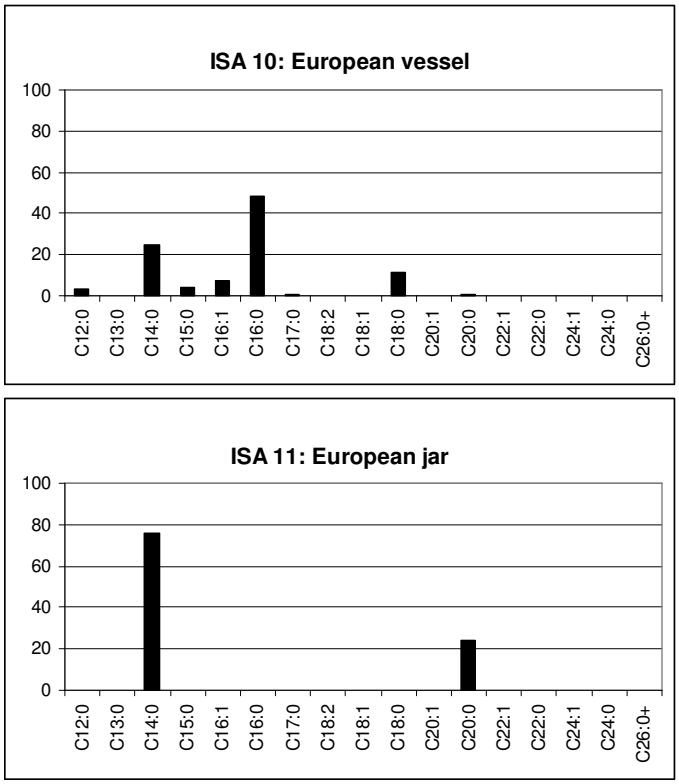
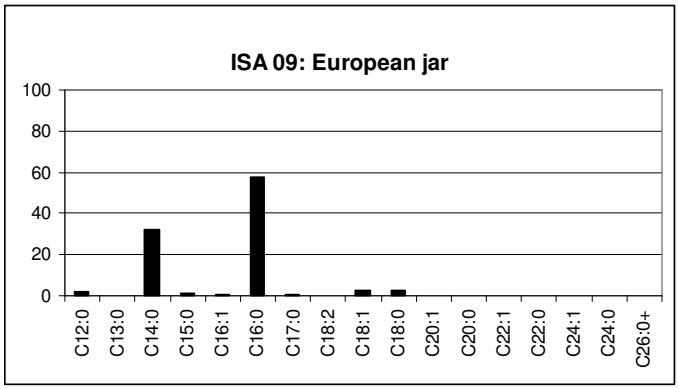


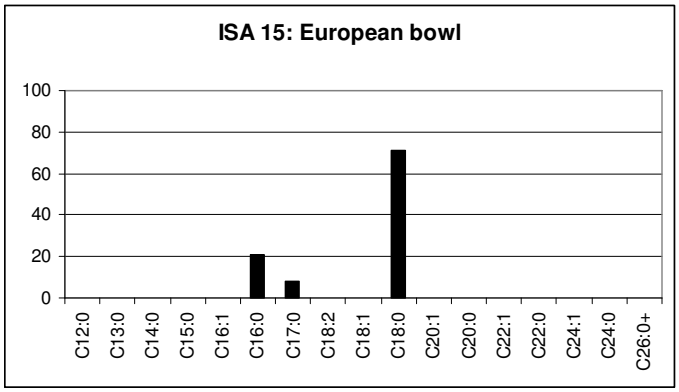
Figure 7.7 Relative abundances of fatty acids in residues from Las Coles.

Fatty acids were not recognized in the GC-MS analysis of four sherds. These were from a vessel of undetermined shape (ISA 01), a canteen-like cantimplora (ISA 02), a bowl (ISA 05), and the control mentioned above. The control contained only squalene, and it was present at a level significantly higher than any other sherd in the collection. While the remaining three samples had no fatty acids, identification of their absorbed residue was possible based on the levels of other lipids. Each shows a solely plant-based origin of the vessel contents.

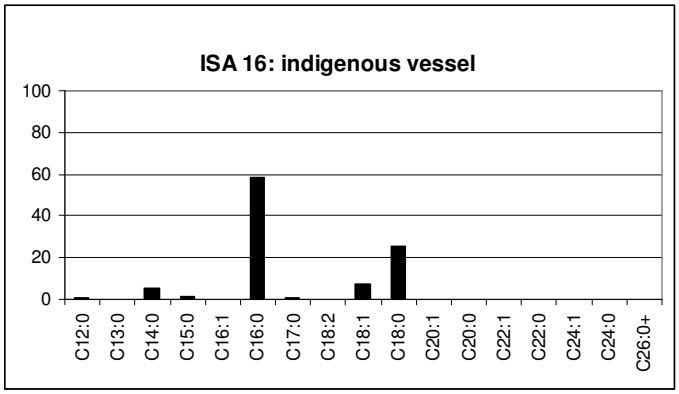
Triacylglycerols were present in the cantimplora, and although TAGs are usually associated with animals, they are also found within oil-bearing seeds of many plants.



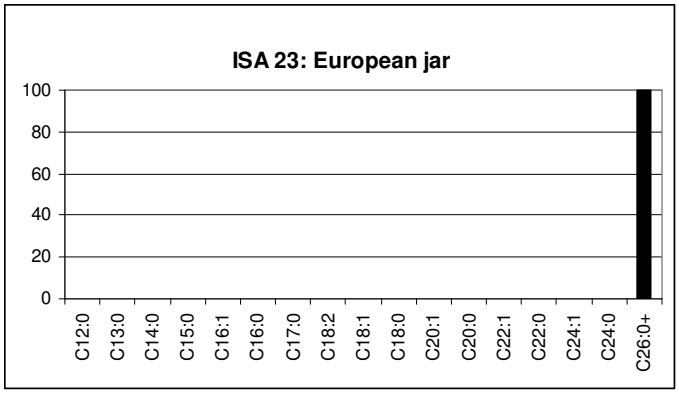
Possible sources:
Fish
Greens
Mammal
Mollusk



Possible sources:
Fish
Greens
Mammal
Ruminant

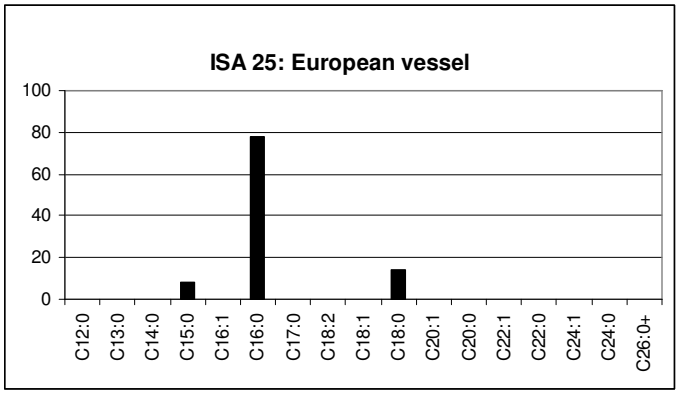


Possible sources:
Fish
Greens
Mammal
Mollusk
Ruminant

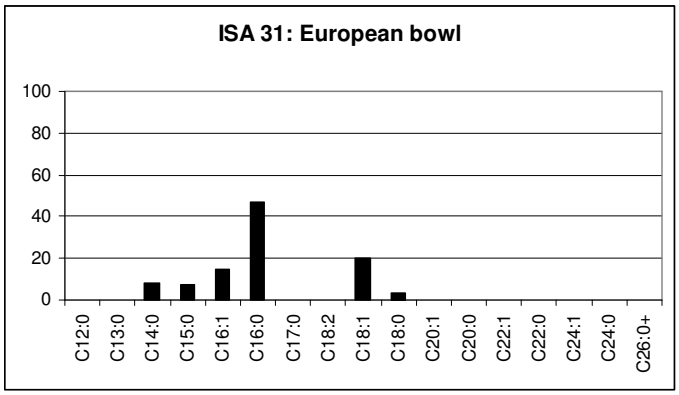


Possible source:
Greens

Figure 7.8 Relative abundances of fatty acids in residues from La Isabela.



Possible sources:
Greens
Mammal



Possible sources:
Fish
Greens
Mollusk

Figure 7.8 Relative abundances of fatty acids in residues from La Isabela (continued).

Combined with the alcohol residue, it is possible that this vessel once contained plant oil, possibly olive oil brought from Europe to the Caribbean as a taste of home for some colonist. This would be an effective use of the vessel, as its restricted orifice and handles that extended to or past the rim make manipulation of the contents difficult but facilitate pouring of liquids.

The sherd from La Isabela that appeared to be of indigenous manufacture (ISA 16) yielded interesting residues. The vessel type cannot be reconstructed because the recovered fragment is small, flat, and from the body of the pot. As such, it gives no clue as to the shape or form of the vessel. The compounds absorbed into the sherd, however,

do provide indications as to its use. The amount and type of fatty acids are strongly associated with those found after processing land mammals. There are few traces of lipids from fish, and only relatively small amounts of long-chain alcohols from plants. The distribution of compounds matches most closely with the pattern produced by cooking ruminant animals or their milk.

The sherd was excavated from a depth of more than 25 centimeters below the ground surface in the area then covered by a 20th century town. It is unknown if the sherd was deposited there prior to the arrival of the Europeans or after. In either case, the potential identification of the residue is one of great interest. Either the Taínos in the pre-Columbian period cooked a non-ruminant food source that resulted in the residue signature of cattle, goats, or sheep, which would mean samples from other studies may be mistaken in their identification, or the indigenous vessel was used to cook European food soon after the meeting of the two cultures. It may have been obtained via trade or collected by a European settler and then used for domestic purposes. Or it may have been used by a Taíno woman cooking in a colonist's house. Conversely, the vessel may have remained in the Taíno community, but used to cook meat acquired from the Europeans. In any case, it is evidence of close interaction between the two cultures soon after contact.

At least one of the five sherds of European origin from La Isabela that exhibited fatty acids had a similar pattern of residue signifying ruminant animal meat. The bowl of which ISA 15 was part had many of the same characteristics signifying the mixed use of ruminants, plant greens, and fish. Additionally, sherds from another bowl (ISA 31) and an undetermined form (ISA 25) may have once contained ruminant tissue or milk, based

on a ratio described by Reber (2001). Yet these samples do not have the abundance of $C_{18:0}$ or branched $C_{17:0}$ fatty acids that are typically seen as biomarkers. Instead, ISA 25 appears to have contained another land mammal combined with plant greens, while ISA 31 held fish, mollusks, and greens.

The remaining samples from La Isabela are from two jars. One of these (ISA 09) contained plant greens, fish, land mammals, and mollusks at one time in its useful life. The other (ISA 23) was used only to cook or store plants. These are representative of the wide variety of food types processed in European vessels by the supposedly starving settlers.

Comparing Vessels, Cultures, and Food

In general, the vessels tend to show a mix of plant and animal products used by all cooks, regardless of culture (see Table 7.1). Whether the heterogeneity represents a repeated practice of cooking dishes with several ingredients or the production of a series of dishes based on a single different ingredient each time is unknown. The results could create the same amounts of certain compounds in the absorbed residue. Even so, some patterns of food use and cultural preferences appear.

The dedicated form of the burén and cantimplora and the residues found in the examples of each in this study are discussed above. The more abundant and general bowl and jar vessels do not show any particular specializations. There is no correlation between the presence of fish rather than mammal residue and indigenous bowl use, as 10 of the 16 bowls (63 percent) had the presence of both types of meat. For Taíno jars, the frequency was only three of six (50 percent) with fish, but all six contained tissue from

Table 7.1 Assignment of sample residues to food categories.

No Residue	*Fish Only*	*Greens Only*	*Mammal Only*	*Controls*
CO 01	ES 04	ECZ 02	ES 06	ISA 12
ES 09		ES 02	PER 03	TAM 30
PER 05		ISA 01		
		ISA 02		
		ISA 04		
		ISA 05		
		ISA 23		
		LEO 07		

Seed/Fish/ Mollusk	*Seed/Mammal*	*Seed/Mammal/ Greens*	*Seed/Mammal/ Greens/Mollusk*	*Seed/Mammal/ Fish/Mollusk*
TAM 21a	ECZ 13	TAM 09	TAM 16	TAM 11*
	PER 02	TAM 24		
	TAM 12			

Greens/ Mammal	*Greens/Fish/ Mollusk*	*Greens/Fish/ Root*	*Greens/Fish/ Mollusk/Root*	*Greens/Fish/ Mammal*	*Greens/Fish/ Mammal/ Mollusk*
ECZ 11	ES 10	LEO 02	LEO 04	ES 07	ECZ 05
ECZ 15	ISA 31	TAM 18b	TAM 18a	ISA 10	ISA 09
ISA 11				ISA 15*	ISA 16*
ISA 25				TAM 07*	TAM 02
TAM 08					TAM 05
TAM 10					TAM 13*
TAM 14					TAM 22*
TAM 15					TAM 23a*
					TAM 25a*
					TAM 25b
					TAM 26*
					TAM 27*
					TAM 29

* Noted presence of ruminant animal.

land mammals. Jars have a more restricted orifice than bowls, and are thus suited for cooking processes where limited evaporation is desired. Since the Taíno boiled much of their food rather than frying it (Veloz Maggiolo 1997), a jar shape would assist in slowly stewing or braising hutia and dog meat for a more tender meal.

There appears to be little difference between the Taíno decoration styles and the foods they contained. Meillacan and Chican designs were each noted on nine sherds. The sherds were equally as liable to be used for processing fish, land mammals, or plant material. The only divergence occurred in the analysis of ruminant residue. Meillacan decorations were found on two of the seven indigenous sherds exhibiting lipids common to cattle, goats, and sheep. The rest were undecorated, and Chican styles were not seen at all. The sample size is too small to make any generalizations from this, but it is interesting in that the Meillacan were thought to be from an earlier time in Caribbean history, and the Macorís that remained were located in the far northeastern portion of the island (see Chapter 3). This style of decoration, if it was related to the Macorís people rather than to the Taíno generally, would be the less likely of the two to have ruminant residue as it was the farthest removed in terms of time and distance from the presence of European livestock. Since the opposite is true, it weakens the accepted paradigm of distinct Classic Taíno and Macorís cultures and adds to the evidence that decorations are either simply consumer or producer choices in terms of pottery styles or are related to a division yet unknown to archaeologists.

A cultural comparison between the Europeans and the Taínos as a whole is also informative. The foods contained within the dishes used by the colonists were generally simpler than those found in indigenous pots. Nearly half (n=5) of the 11 European

vessels studied exhibited residue only from plant greens, and 64 percent (n=7) had two or fewer ingredients. Taíno sherds, on the other hand, showed more diversity of component foods. Of the 33 indigenous vessels represented, 52 percent (n=17) had three or more types of food residue absorbed within the ceramic walls, and only about 15 percent (n=5) had one food identified. Two sherds had no residue, suggesting they were used either for a cooking process that did not facilitate the absorption of lipids or did not hold cooked food at all.

The Taíno were known to use a form of cooking that is traditional to people of tropical forests (Keegan 1997) and remains popular with West Indians today. A stew of *casirepe*, or cassava juice, and other ingredients is simmered over low heat for long periods of time. Servings are taken from the pot as needed. As days pass, more meats and vegetables are added to replenish the "pepper pot," so named because of the use of chilies as a spice and to cure the meats added to the mix. The expected residue product of a pepper pot would be not unlike the assortment of food compounds that were found in the majority of Taíno sherds. The largest group of samples was those categorized as possessing residue from a combination of plant greens, fish, land mammals, and mollusks. All but one of these nine sherds was of indigenous origin. That one European sherd, as well as the Taíno vessel fragment found at La Isabela, shows that the colonists may not have been as averse to Taíno cooking techniques and ingredients as previously thought.

The cuisine found in 15th century Andalusia was greatly influenced by the foods and cooking wares used by the Moors who occupied Spain and controlled the region for years. Fruits, vegetables, and spices introduced by the Muslims led to an unusually

varied Andalusian diet. The acceptance of these foods, not found in the cuisine of other Europeans, raises the question of whether Columbus and his sailors would be quite so reluctant to adapt novel cuisines as thought. Meals of the region from which most colonists came were usually produced on portable braziers rather than the large open hearths common to colder northern Spain (Lister and Lister 1987). The braziers had a base into which the fuel was placed and over this rested a cook pot. As a result of this technique, most foods were simmered in water or oil. Many braziers could be used at one time in the kitchen, producing many one-dish meals. The typical fare was made of braised vegetables, with meat added on special occasions. Other dishes included fried fish, vegetables, and pastries served with slowly simmered beans or rice mixtures called *menestras*. Although the colonists used fewer ingredients in their stews, the idea was similar to that of the Taíno pepper pot.

The Europeans did not take advantage of all the local resources, however. The residue from seeds, nuts, and berries were not found within colonial vessels, nor was the presence of roots noted. Even more unexpected was the lack of mollusk usage. While one of the largest components of excavated material at many locals sites are the shells from oysters, conchs, and the like, lipids from shellfish were recovered from only two European sherds. The Taíno used mollusks in 45.5 percent of their vessels (n=15) and seeds and roots in more than a third (n=12). There were clearly some different preferences in cuisine between the cultures.

It appears that the interaction between the two groups of people in terms of culinary practices was remarkably complex. Not only did the Europeans make use of some local foods and techniques while at the same time ignoring others, but the Taínos

were utilizing the new menu items brought from abroad. Of the eight samples that yielded residue associated with ruminant animals, nearly all (n=7) were of indigenous origin. Admittedly, this is a small sample size on which to base conclusions, but it is of interest nonetheless.

When ruminant residue was present, it was always in combination with both plant materials and fish. Usually mollusks would be cooked with the ruminant meat as well. This suggests the Taíno were making use of the cattle, goats, or sheep of the Europeans but doing so in their own way. The mix of food types in a single vessel would be expected if the ingredients were cooked together in a pepper pot. Similarly, the lack of ruminant residue on European sherds may be a consequence of expediently roasting the meat or frying it rather than stewing it. The colonists would not have ignored their livestock after going through the trouble of carrying the animals on the ships, especially if the settlers were starving as was reported. But the cooking method they employed may have not left behind any residual evidence. The more elite colonists would have also had access to metal cooking pots and pans, into which the residues would not have been absorbed.

The European colonists, it seemed, had narrow dietary preferences. Evidence for this comes from the lack of variety in the foods they ate, and more importantly, those classes of food they avoided. The cooking techniques used by the Europeans certainly differed from the pepper pot of the Taíno, and the result is a discrepancy in absorbed residues, but it is hard to understand why they were slow to learn of the foods used by the local people, who had thrived in the area for hundreds of years by exploiting the abundant natural resources. The knowledge the Taíno possessed about the plants and animals of

the islands were ignored and dismissed by the Europeans (King and Dudley 1991). The species brought by the colonists, on the other hand, were adopted relatively quickly by the indigenous people. There is evidence of interaction in both directions in the food residue absorbed into the ceramics of the two groups. There are also signs of difficulty. Support for the idea of a starving settler, though, is not to be found.

CHAPTER 8:

A DISCUSSION OF CULTURAL EXCHANGE

Introduction

The first of the two primary objectives of this research was to test techniques that could to extract and identify particular organic compounds from food sources absorbed into ceramic vessels. At this time, no such research has been done on material recovered from the islands of the Caribbean Sea. Most of the absorbed residue analyses have been conducted on artifacts from Europe and a few from North America, regions of the world unaffected by the warm and humid conditions found in the West Indies. Furthermore, the food residues observed from these locations are vastly different from that of the native Caribbean flora and fauna. Efforts were made in this study to assess the levels of preservation found in materials recovered from tropical environments.

If residues did remain, and it was established in Chapters 5 and 6 they did, it is important to know from which particular contexts the compounds can still be recognized and in what quantities. Could the plethora of artifacts from previous excavations, placed in storage and currently unused, provide the same amount of data as freshly excavated sherds? Do the vessel fragments taken from fresh-water springs maintain lipid levels similar to those from a sandy soil matrix? These questions and more were considered during the course of this study.

Curated artifacts did indeed produce identifiable compounds. Submerged artifacts did not, at least in the few samples analyzed from Los Hoyos de Molina. This may be because the sherds were in water too shallow to provide an anaerobic environment or because were not used to cook food. They may have held ritual offerings or only water. The results of the research are presented in a summary fashion in this chapter.

The other goal was to apply the technique found to best extract lipids from these samples to the problem of determining the diets of people living in the past. Through an analysis of the food choices of different groups, an archaeological reconstruction of daily behavior could be started. The quotidian existence of cooks and those they fed is influenced by environment but also by culture. The meals people eat every day are tied to the ways they identify themselves. It is an anthropological truism that traditional diets may be preserved even at the cost of much suffering (Fernández-Armesto 2002; Roosevelt 1987). Any changes in subsistence patterns seen in the Europeans that first colonized the Americas, or in the Americans that first encountered the colonists, would therefore reflect an important interaction between the cultures. As noted in Chapter 7, indications were found in more than a few archaeological sherds of shifts in culinary practices occurring in both cultures. These data are reviewed here as well.

This research proved to have its limits, particularly in terms of issues of identification techniques. Even so, absorbed residue analysis proved to have some utility in solving specific archaeological questions. It can provide information regarding subsistence at sites where the typical evidence, such as faunal and botanical remains, is scarce or poorly preserved. The limitations facing those attempting to employ this

research, as well as the potential for future applications, are discussed further in this chapter.

Objectives and Results

The Europeans that first came to La Isabela brought with them supplies and provisions enough to last for months. They did not know what local resources could be exploited for food. Moreover, they certainly wanted to assuage any potential trials and tribulations in the new lands with "comfort food," familiar dishes from home. They also had to consider how to continue the Catholic mass, with the necessary serving of bread and wine at Holy Communion, in a far away land. They continued to import European crops and livestock, even after the former failed to grow well in many attempts. As long as land was available to cultivate the recognizable plants and vegetables of Spain, Italy, and the rest of the Old World, there was little incentive to experiment with indigenous flora.

In most situations, change typically proceeded only after much hesitation. But in La Isabela, it appears the colonists quickly adapted at least some local cuisine that was strange, exotic, potentially poisonous, and necessitated learning new types of production and consumption. Of the 11 European-style sherds analyzed, more than a third (n=4) had residue from what can only be assumed to be local fish and mollusk species. Of course, these were sailors used to supplementing their larder at sea with fishing lines and harpoons, no matter where they traveled. Fewer than 50 percent of the vessels represented (n=5) once contained the meat of land mammals other than cattle, goats, or sheep. Aside from the pigs brought over on the ships, a likely source would be guinea

pigs, hutia, and the indigenous dog. Chroniclers report that the colonists ate dogs during the famines of 1494 (Sauer 1966), a sign of the desperate times. Every one of the European sherds, regardless of form, had residues from plant greens, although none from nuts, seeds, berries, or roots. If the compounds were from indigenous flora, the colonists were making conscious decisions based on particular plant aspects that appealed to them. They were cognizant of the plentiful resources available in the West Indies and made choices about foods which suited their preferences.

The above conclusions are based on the assumption that the European ceramic vessels were not used prior to their arrival at La Isabela. If the vessels were simply pieces carried by the settlers from their homes in Spain, the food residue would have little meaning to this study. Most of the ceramics shipped from Europe were of the ubiquitous olive jar form, the most prevalent ceramic type found in colonial sites across the 15th and 16th century Americas (Marken 1994). Olive jars, like the Greek and Roman amphorae from which they are descended, and wooden barrels were the primary shipping and storage containers used in ocean transport. The curved sides of olive jars fit well against the hull, and the shape provided structural integrity and easy closure. The olive jars were used to export food to the colonies, but also oil, seed for sowing, and nearly anything else that would fit. These vessels would undoubtedly have residue from the European continent, but they almost always had a glazed interior that prevented absorption and thus were not included.

All of the pieces analyzed in this study were of unglazed coarse earthenware types, not the typical glazed serving dishes one would find setting a 15th century European table and much too small to be used in transporting cargo. These were the

vessels used in the kitchen for food storage and production, the pots and pans of the times. Most were utilitarian bowls and jars of basic construction and without any ornamentation. The forms seen in the collection are easily broken, due to their construction and repeated hard use in producing food. Known as *loza común* and believed to be produced locally (Ortega 1980), they are thin-walled with sand temper and are fired only at relatively low temperatures. A vessel of this sort would have a short useful life. An ethnographic study of comparable vessel sizes and functions shows less than half of jars survive for more than 12 months before breakage, and only around 10 percent of food bowls remain after one year (Rice 1987). Since the colonists spent several months aboard ships – a location not conducive to vessel preservation – one would expect most bowls and jars brought from Europe would need to be replaced soon after arrival in Hispaniola.

The colonists likely made the utilitarian pottery at a kiln that has been found at Las Coles (Cruxent 1990). Chemical analysis of soil samples and coarse earthenware sherds supports this hypothesis. The colonists appear to have manufactured pots at Las Coles with much the same temper and possibly the same clay source as the Taínos, whose sherds are compositionally related (Deagan and Cruxent 2002a). Thus, the food residue within the vessels would necessarily be of post-contact origin.

Even so, it is interesting that the colonial sherds, collected from a wide variety of vessel forms and recovery locations, yielded less meat residue than that derived solely from plant greens or plants in combination with fish. As mentioned above, less than half of the sample (n=5) had compounds identified as coming from land mammals. The infrequency (compared with 72.7 percent of indigenous sherds) may not be due to the

aversion of the Europeans to indigenous fauna, but rather because of the strong Catholic nature of the colonists. In the 15th and 16th centuries, the number of religious day during which the consumption of meat was forbidden comprised nearly half the calendar year (Braudel 1973). Whereas fish or shellfish would be permitted, eating meat from even their own livestock was forbidden. The prohibition, if strictly followed, would greatly reduce the frequency at which characteristic meat residue would be absorbed into the European pots. Still, the analysis is powerful enough to identify a material cooked in a single episode if the conditions are right, so a taboo that results in the frequent, but not complete, avoidance of meat cannot fully account for the paucity of mammal residue.

Anthropologists have a propensity for explaining apparently illogical behaviors of people through a lens of culture. This may be best exemplified by Leví-Strauss, who stated "natural species are chosen not because they are 'good to eat' but because they are 'good to think'" (1963: 89). But an analysis of subsistence patterns that is based strictly on the symbolic function of foods discounts variables that are equally as valid. The economic context of decision making must also be considered. Elements such as seasonality of planting and harvests, nutritional values, and the energy costs of farming and hunting particular species also have influence on the choices of what and when to eat.

A material explanation for the low level of mammal residue, especially from ruminant animal sources, is that the size of colony could not be fully supported by the number of cattle, pigs, and sheep they carried on the ships. As more colonists were packed into the area around La Isabela, they may have been forced to move down the food chain to less satisfying items then they wished to consume (Harris 1987). Although there were plenty of native resources available, the feeling of starvation reported in the

chronicles may have come from an inability to eat the foods normally found home. The amount of meat was restricted, the non-native crops were not growing, and there were many tasks at hand more potentially rewarding than that of farming. Add to these conditions that fact that the colonists were virtually all men who were trying to advance in social status. Any time spent doing the menial work of the kitchen would disgrace the cook and associate him with the lower classes. The Europeans found themselves in an ironic circumstance much like that of a sailor dying of thirst while surrounded by the water of the ocean. The food was around them, but they were not able, or did not want, to consume it.

The sherds from indigenous sites surrounding La Isabela, on the other hand, frequently contain non-native foods. From the presence of plants of the Brassicaceae family (such as cabbage) to the residue of ruminant animals, the Taíno appeared to have utilized European foods in their own meals. The compounds associated with material from cattle, goats, and sheep were recovered from 35 percent (n=6) of the sherds excavated from El Tamarindo, the large Taíno village site overlooking the Río Bajabonico and the Atlantic Ocean. The only other indigenous vessel fragment containing ruminant residue was the one found at the site of La Isabela itself. Since cud-chewing herbivores are not indigenous to the Greater Antilles, at least not after the last Ice Age, the rationale that best explains their presence in Taíno vessels is that the Taíno were cooking cattle, goats, or sheep for themselves.

The production of dishes made from ruminants and by indigenous cooks could have been at the request or order of European settlers. Yet El Tamarindo is almost two kilometers away and just under one hundred meters above La Isabela and Las Coles. The

vessels studied were of relatively small size and would not make suitable containers for carrying a large amount of foods down the ridge to the colony. Most likely, the cattle or goats were obtained by the Taíno and exploited for their own use. El Tamarindo was therefore already occupied at the time of contact or founded shortly after 1594 by Taínos wishing to escape European control. The site has not been assigned to a specific range of years using absolute dating methods, but the decoration style of the pottery recovered from there suggests an occupation between A.D. 1200 and 1500. It is remarkable that the Taíno adopted European food species into their own diets within a few years, whereas the colonists were thought to be so averse to a change in subsistence patterns.

The ruminant material was always found in combination with fish and plant greens or seeds. This was a common pattern for the majority of indigenous sherds. A total of 58 percent (n=18) of the Taíno vessels with residues exhibited compounds from three or more different food types. The people of the West Indies are known to have regularly made stews from a wide variety of ingredients. This research provides further support for the use of such pepper pots by Taíno cooks. The mixed residue was found in all the vessel types, included a burén that is typically thought to serve only as a griddle for casabe. It appears that the Taíno would sometimes augment the cassava flour used to make casabe with plant greens, fish or fish oils, and even material from land mammals.

Only five indigenous sherds had residues from just one food category. Most of these (n=3) were recovered from a deposit near Punta Rucia that also yielded two human skeletons. Although these artifacts were not systematically excavated, and thus much or all of the context is destroyed, the implication is that the vessels served as containers for food offered to the dead. One sherd had only fish lipids present, another had only land

mammal material, and a third showed nothing besides plant greens. The remaining sherd from this site had a mixture of the above three categories. Little is known about the Taíno rituals surrounding death, and this research can be easily expanded to increase the knowledge about this important part of the worldview of the Caribbean people.

Two of the sherds from Punta Rucia also contained dehydroabietic acid, a compound found in the resin of coniferous trees. If these vessels were used in a ritual context, it is possible that they became infused with DHA from the burning of incense or a copal-like material. An extensive literature search found no other reports of copal use in Taíno culture, probably due to the ephemeral existence of the evidence in the archaeological record and the lack of comprehension of the authors of the few ethnohistoric accounts of Taíno rituals. The compound DHA was not seen in any of the other samples outside of those from La Isabela and Las Coles. Here the presence of DHA in every sherd may be associated with the pine chest used in post-excavation storage or the many fires that plagued the settlements in their short existence.

Practical Limitations

Contamination could be one of the greatest factors in decreasing the accuracy of residue analysis. The implementation of a careful protocol and the testing of control samples, however, extensively reduces the probability that the compounds being studied are from something other than the material cooked or stored within a pot. Tests were conducted comparing the lipids found in sherds and those recovered from associated soils and there were noticeable difference between the two types of samples. Of the five soil samples analyzed using gas chromatography-mass spectrometry (GC-MS), one had no

lipid residue at all, and another had only traces of plant material. The other three showed plant material in combination with fish, mammal, or mollusk residue but the amount and variety of compounds differed from that of the tested sherds. Further, sherds from three sites contained no residues whatsoever. The absence of lipids in vessel fragments recovered from the same depositional contexts as the other sherds from these sites suggests that materials present in the ground are not absorbed in the same manner as those found after cooking. Several other researchers have examined the influence or migration of soil lipids on food category identification and have found only a negligible impact (see Chapter 6).

Contamination through handling was also investigated. The experimental sample that intentionally collected skin, hair, and possible laboratory contaminants provided a baseline against which the presence of naturally occurring cholesterol and other compounds were measured. Removing one or two millimeters from the exterior surface of each sherd with a modeling drill reduces the presence of residue adulteration due to conditions following the discard of a vessel. The strict use of nitrile gloves, as well as solvent-rinsed or annealed glassware and laboratory equipment, diminishes the risk of introducing inauthentic compounds. When unknown or unanticipated lipids are found in the samples, their possible origin can be more easily identified when these controls and protocols are in place.

Dissimilar rates of decomposition may also have an effect on the residue contained within a sherd. This variable is much harder to control than that of contamination. For instance, if a bowl was used to cook a meal which was then served on a dish, one would assume the residue from the foods used would be found in both

vessels. But if the bowl was returned to the fire and cooked the meal again the following day, it would be exposed to thermal degradation and the dish would not. As a result, the residues may not be interpreted as being from the same food source after GC-MS analysis.

In the same way, foods in their raw states have ratios of residues dissimilar to foods that have been cooked. Even different cuts from within a single animal or various parts from the same plant have distinctive compound signatures. Cooking the liver of a duck produces a slightly different result from boiling its bones for stock. The profiles of seeds or nuts are not the same as that of greens, and immature berries have distinct compounds from overripe ones. Nevertheless, even if determining the exact species cooked within a pot is impossible, a more general reconstruction of the diets of the Taíno and colonial Europeans is useful, considering how little is known about the cooking methods and subsistence base of the former and the biases surrounding the information provided by the latter.

The process of residue identification used in this research accounted for the problems of degradation and species variability by employing specific biomarkers and the combination several fatty acid ratios. The reconstruction of the food sources responsible for the lipids absorbed into vessel walls was not as much a quantitative procedure as it was a qualitative analysis. During the course of this study, although it was much desired, it was learned that values could not be just plugged into black box of formulae and result in the source of the food. Ratios of fatty acids and other considerations have to be evaluated in terms of the context of the sherd, the identification

confirmed by the most lipid comparisons, and the probability of a genuine source for the compound.

As many as a dozen different methods were used to reconstruct the food source for each sample (see Appendix D). At times, applying the procedures used by other researchers resulted in more than one possible source for the same groups of lipids. A problem with using ratios to determine residue origin is that the absence of one important component produces an unreliable result. Other variables had to be assessed to corroborate the identification. Ratios or biomarkers that utilized separate fatty acids were all considered, and the ultimate identification was the product of weighing the predictive nature of all the measures.

Because of the novelty of absorbed residue analysis and the individuality of each region in terms of food resources and environment, a set of research guidelines does not yet exist. Successful classification of food sources often requires that original strategies be employed for the different sets of compounds extracted from the samples. Still, although this process was lengthy and involved, it produced a more comprehensive, thorough, and confident reconstruction of the vessel contents. Residue analysis, like many scientific techniques, is best done by a skilled researcher who can apply previous experiences in appraising the quantity and quality of the lipids present in the sherds.

Research Possibilities

It is possible that the identification of certain lipid profiles may have been facilitated by comparison with degraded residues produced in the laboratory. A number of previous studies have experimented with plants and animals commonly found in the

research location (e.g., Coyston 2002, Eerkens 2001, Malainey 1997). Material from likely food sources was boiled in replica pots, after which the lipids were extracted and analyzed using GC or GC-MS techniques. The signatures of each substance were then known to the researcher and could be matched against the profiles found in archaeological sherds.

Experimentally produced residues were not used in this study for a number of reasons. As this was the first attempt to extract compounds from material recovered in the Caribbean, it was unknown if residues would even be preserved in the hot and humid climate and specific soil conditions of the region. Thus, efforts were concentrated on proving the feasibility of the method and then, when extraction was successful, refining the protocol. Furthermore, much of the flora and fauna of the West Indies is unique and not available outside of the islands. Some species have even become extinct after the arrival of the Europeans. The small, "barkless" dogs indigenous to the Greater Antilles no longer exist, and the hutia is sighted only rarely. These creatures and many plants cannot be found in local markets. Even if samples were somehow procured, transporting them via air into the United States would not be without its own problems. Regulations on the import of plants and animals are strict, and the material would begin to degrade rapidly.

Many of the once exotic flora are now available in specialty stores or from internet merchants, but the species have usually been hybridized and may no longer contain the same compounds in the same quantities as when they were used in the 15th century. Cassava, for instance, can now be found with relative ease but not the bitter variety that the Taíno cooked. Iguana or land crabs may also be purchased in the United

States, but they have fed on vastly different food types, and their tissue may no longer reflect their indigenous habitats.

This is not to say it is impossible to acquire samples from the Caribbean or analogous species which could serve as an alternative. The plant and animal tissue could be dehydrated or freeze dried and the necessary permits for transport attained. In fact, now that the technique has been refined and found successful, potential food sources identified, and amounts of needed samples needed, attempts will be made to test a number of the various indigenous species probably used as foods by the Taíno and colonists.

Experimentally produced residue, however, cannot ensure accurate identifications. It is not possible to replicate the many variables and complex factors that create the absorbed compounds, nor can the rates of degradation and preservation be predicted. It is not known how long the foods were cooked or at what temperature, in what mixture of water and casirepe (the juice that results from processing manioc) the pepper pot was made, and what cuts of meats were added or in which order. Preparing a variety of dishes with slight changes in all these elements would still not result in lipid profiles that are necessarily similar to that found in the archaeological sherds. At this time, little is known about the how fatty acids and other compounds are absorbed, what ensures their preservation, and how quickly they degrade. There are a plethora of factors that must be considered: porosity of the vessel and firing temperature, organic content and condition of the soil, ambient heat and moisture levels, and post-excavation methods of cleaning and storage, among others. The combination of pots, ingredients, cooking methods, depositional environment, and archaeological processing are countless. Each of

these variables influences the type and amount of residues present, and they cannot all be exactly replicated in the laboratory.

In spite of the limitations of absorbed residue analysis, the technique proved useful in this study for establishing the origin of materials found within vessels used in the past. It helped explore and explain the relationships between two cultures at contact. When the people and the foods they ate were compared, noteworthy patterns of interactions emerged. The European colonists, although they were not able to produce wheat bread, wine, or olive oil, did not seem to be actually starving. They did, however, make interesting choices in the foods they ate. The Taínos appeared to quickly adopt non-native cuisine, possibly due to their declining situation. The small number of Chican and Meillacan sherds contained very similar residues, adding to the hypothesis that the two groups were not as distinct as previously thought. Further research can be done by examining the foods in other areas of the Caribbean and at other times of contact.

The technique is probably best applied in situations where other evidence of food remains, such as bones or seeds, are poorly preserved or otherwise scarce. Even when faunal or floral remains are found at a site, they cannot be directly associated with production methods, while the absorbed residue tells of what was made and how. The compounds can also be used to discern patterns of cooking and resource exploitation. This is especially of benefit now that isotopic ratio analyses of human skeletal material are rarely performed due to the destructive nature of the method and increased sensitivity to the desires of descendant communities.

Furthermore, the possibility of identification of residues in curated artifacts, as shown in this study, has the potential to answer many questions that were previously

unable to be resolved. Flotation techniques, which recover very small fragments of organic matter, are used at some archaeological sites. Most excavations, though, occurred prior to the development of this technology, did not have a research question that necessitated its use, or were without the financial or logistical support for its employment. Even when all efforts are made to recover faunal and floral remains, the evidence can still be elusive. Excavators of La Isabela and Las Coles could not make any conclusions regarding the diet of the colonists after years of well funded research. The data, though, were available to be extracted and identified using GC-MS. Residue analysis is an ideal alternative method to recognize the plant and animal resources exploited at other sites as well.

Material from museum collections or other assemblages of irreplaceable artifacts may also have their absorbed compounds investigated, particularly if the non-destructive protocol developed in the course of this research is used. The technique of sonicating sherds and intact pots in a solvent bath still needs to be refined, but the early evidence shows that it is possible to extract useful data without completely pulverizing the valuable artifact. Other advances in terms of improved sensitivity of instruments and the development of large libraries of lipid spectra will further enhance the process of GC-MS analysis. In addition, the availability of gas chromatographs and mass spectrometers in laboratories will increase as the price of the instruments continues to fall, and their utility becomes more widely realized. As the technology becomes cheaper, better, and more accessible, investigations using absorbed residue analysis should become more commonplace in the future.

The information gained by applying residue analysis to archaeological problems is not limitless. All research methods and laboratory techniques have certain restrictions. But the potential that absorbed lipids have for helping to reconstruct the past is large and should continue to be pursued. Not only can it help in the formation of models of cultural exchange and provide fuller perspectives on the behaviors of cooperation and conflict, as was begun with this research, it can be of use in studies of population movements or the initial development of pottery. By applying a heretofore untested biochemical analytical technique to the archaeological materials found in the Caribbean, comparable research may produce data on the importation of particular flora to the region, the ingestion of substances for medical or ritual practices, or the shifting behaviors of marine versus terrestrial resource exploitation. The study of absorbed organic residue can strengthen current interpretations or support shifts in the accepted paradigms. Considering that knowing how people in the past lived in, and made use of, their environment is an integral part of understanding almost all human behavior, absorbed reside analysis appears to be an important new tool in the field of archaeology.

REFERENCES CITED

Alegría, Ricardo E.
1983 *Ball Courts and Ceremonial Plazas in the West Indies*. Publications in Anthropology, No. 79. Yale University Press, New Haven.

Armelagos, George J.
1994 You Are What You Eat. In *Paleonutrition: The Diet and Health of Prehistoric Americans*, edited by Kristin D. Sobolik, pp. 235-244. Center for Archaeological Investigations, Occasional Paper No. 22. Southern Illinois University, Carbondale.

Augelli, John P.
1989 Geographic Parameters in West Indian History. In *Middle America: Its Lands and Peoples*, edited by Robert C. West and John P. Augelli, pp. 60-79. 3rd ed. Prentice Hall, Englewood Cliffs, NJ.

Badler, Virginia R., Patrick E. McGovern and Rudolph H. Michel
1990 Drink and Be Merry! Infrared Spectroscopy and Ancient near Eastern Wine. In *Organic Contents of Ancient Vessels: Materials Analysis and Archaeological Investigations*, edited by William R. Biers and Patrick E. McGovern, pp. 25-36. Museum Applied Science Center for Archaeology, University of Pennsylvania, Philadelphia.

Beeker, Charles D., Geoffrey W. Conrad and John W. Foster
2002 Taíno Use of Flooded Caverns in the East National Park Region, Dominican Republic. *Journal of Caribbean Archaeology* 3:1-26.

Bender, D.A.
1997 *An Introduction to Nutrition and Metabolism*. 2nd ed. Taylor and Francis, Bristol, PA.

Bennett, Deb and Robert S. Hoffmann
1991 Ranching in the New World. In *Seeds of Change: A Quincentennial Commemoration*, edited by Herman J. Viola and Carolyn Margolis, pp. 90-111. Smithsonian Institution Press, Washington, DC.

Bethell, P.H., R.P. Evershed and L.J. Goad
1994 The Investigation of Lipids in Organic Residues by Gas Chromatography/Mass Spectrometry: Applications to Paleodietary Studies. In *Prehistoric Human Bone: Archaeology at the Molecular Level*, edited by G. Grupe and J. Lambert, pp. 229-255. Springer-Verlag, Berlin.

Blume, Helmut
1974 *The Caribbean Islands*. Translated by Johannes Maczewski and Ann Norton. Longman Group Ltd., London.

Boswell, Thomas D.
1989 Population and Political Geography of the Present-Day West Indies. In *Middle America: Its Lands and People*, edited by Robert C. West and John P. Augelli, pp. 80-102. 3rd ed. Prentice Hall, Englewood Cliffs, NJ.

Braudel, Fernand
1973 *Capitalism and Material Life, 1400-1800*. Translated by Miriam Kochan. Weidenfeld and Nicolson, London.

Brumfiel, Elizabeth M.
1991 Weaving and Cooking: Women's Production in Aztec Mexico. In *Engendering Archaeology: Women and Prehistory*, edited by J.M Gero and M.W. Conkey, pp. 224-251. Basil Blackwell, Inc., Cambridge.

Caro Alvarez, J.A.
1973 La Isabela, Santo Domingo, R.D. *Boletín del Museo del Hombre Dominicano* 3:48-52.

Charters, S., R. P. Evershed, A. Quye, P. W. Blinkhorn and V. Reeves
1997 Simulation Experiments for Determining the Use of Ancient Pottery Vessels: The Behaviour of Epicuticular Leaf Wax During Boiling of a Leafy Vegetable. *Journal of Archaeological Science* 24(1):1-7.

Charters, S., R.P. Evershed, P.W. Blinkhorn and V. Denham
1995 Evidence for the Mixing of Fats and Waxes in Archaeological Ceramics. *Archaeometry* 37(1):113-127.

Charters, S., R.P. Evershed, L.J. Goad, A. Leyden, P.W. Blinkhorn and V. Denham
1993 Quantification and Distribution of Lipids in Archaeological Ceramics: Implications for Sampling Potsherds for Organic Residue Analysis and the Classification of Vessel Use. *Archaeometry* 35(2):211-223.

Chiarelli, B. and Fernando Luna Calderón
1987 The Excavation of La Isabela, First European City in the New World. *International Journal of Anthropology* 2:199-209.

Christie, William W.
1973 *Lipid Analysis*. Pergamon Press, Oxford.

–.
1978 The Composition, Structure, and Function of Lipids in the Tissues of Ruminant Animals. *Progress in Lipid Research* 17:111-205.

–.
1981 *Lipid Metabolism in Ruminant Animals*. Pergamon Press, Oxford.

–.
1989 *Gas Chromatography and Lipids: A Practical Guide*. The Oily Press, Ayr, Scotland.

–.
2006 The Lipid Library. Electronic document, http://www.lipidlibrary.co.uk/, accessed 1 July 2006.

Cohen, J.M. (editor)
1969 *The Four Voyages of Christopher Columbus*. Penguin Books, Baltimore.

Colombini, M. P., G. Giachi, F. Modugno and E. Ribechini
2005 Characterisation of Organic Residues in Pottery Vessels of the Roman Age from Antinoe (Egypt). *Microchemical Journal* 79(1-2):83-90.

Colón, Ferdinand
1992 *The Life of the Admiral Christopher Columbus by His Son Ferdinand*. Translated by Benjamin Keen. Rutgers University Press, New Brunswick, NJ.

Columbus, Christopher
1989 *The Journal of Christopher Columbus*. Translated by Cecil Jane. Bonanza Books, New York.

Condamin, J., F. Formenti, M.O. Metais, M. Michel and P. Blond
1976 The Application of Gas Chromatography to the Tracing of Oil in Ancient Amphorae. *Archaeometry* 18(2):195-201.

Conrad, Geoffrey W.
2004 Bahía Isabela Archaeological Project Field Notes. Manuscript on file, William Hammond Mathers Museum of World Cultures, Indiana University, Bloomington, IN.

Conrad, Geoffrey W., Christophe Descantes, James M. VanderVeen and Michael Glascock
2005 Compositional Analysis of Ceramic Artifacts from La Aleta, Dominican Republic. Paper presented at the XXI International Congress for Caribbean Archaeology, University of the West Indies, St. Augustine, Trinidad and Tobago.

Conrad, Geoffrey W., John W. Foster and Charles D. Beeker
2001 Organic Artifacts from the Manatial de la Aleta, Dominican Republic: Preliminary Observations and Interpretations. *Journal of Caribbean Archaeology* 2:1-20.

Cook, Noble David
1998 *Born to Die: Disease and New World Conquest, 1492-1650*. Cambridge University Press, Cambridge.

–.
2002 Sickness, Starvation, and Death in Early Hispaniola. *Journal of Interdisciplinary History* 32:349-386.

Copley, M. S., R. Berstan, S. N. Dudd, V. Straker, S. Payne and R. P. Evershed
2005 Dairying in Antiquity. I. Evidence from Absorbed Lipid Residues Dating to the British Iron Age. *Journal of Archaeological Science* 32(4):485-503.

Copley, M. S., R. Berstan, A. J. Mukherjee, S. N. Dudd, V. Straker, S. Payne and R. P. Evershed
2005 Dairying in Antiquity. III. Evidence from Absorbed Lipid Residues Dating to the British Neolithic. *Journal of Archaeological Science* 32(4):523-546.

Copley, M. S., R. Berstan, V. Straker, S. Payne and R. P. Evershed
2005 Dairying in Antiquity. II. Evidence from Absorbed Lipid Residues Dating to the British Bronze Age. *Journal of Archaeological Science* 32(4):505-521.

Copley, M. S., H.A. Bland, P. Rose, M. Horton and R. P. Evershed
2005 Gas Chromatographic, Mass Spectrometric and Stable Carbon Isotopic Investigations of Organic Residues of Plant Oils and Animal Fats Employed as Illuminants in Archaeological Lamps from Egypt. *Analyst* 130:860-871.

Coyston, Shannon
2002 *Noble Chemists and Archaeologists: Chemical Analyses of Food Residues from Ancient Maya Vessels.* Ph.D. dissertation, Department of Anthropology, McMaster University.

Craig, Oliver E., Gordon D. Love, Sven Isaksson, Gillian Taylor and Colin E. Snape
2004 Stable Carbon Isotopic Characterisation of Free and Bound Lipid Constituents of Archaeological Ceramic Vessels Released by Solvent Extraction, Alkaline Hydrolysis and Catalytic Hydropyrolysis. *Journal of Analytical and Applied Pyrolysis* 71(2):613-634.

Cranwell, P.A.
1981 Diagenesis of Free and Bound Lipids in Terrestrial Detritus Deposited in a Lacustrine Sediment. *Organic Geochemistry* 3:79-89.

Crosby, Alfred W.
1986 *Ecological Imperialism: The Biological Expansion of Europe, 900-1900.* Cambridge University Press, Cambridge.

–.
1991 Metamorphosis of the Americas. In *Seeds of Change: A Quincentennial Commemoration*, edited by Herman J. Viola and Carolyn Margolis, pp. 70-89. Smithsonian Institution Press, Washington, DC.

–.
2003 *The Columbian Exchange: Biological and Cultural Consequences of 1492*. 30th Anniversary ed. Praeger Publishers, Westport, CT.

Cruxent, José María
1990 The Origin of La Isabela: First Spanish Colony in the New World. In *Columbian Consequences, Volume 2: Archaeological and Historical Perspectives on the Spanish Borderlands*, edited by David Hurst Thomas, pp. 251-259. Smithsonian Institution Press, Washington, DC.

Curet, L. Antonio
1997 Technological Changes in Prehistoric Ceramics from Eastern Puerto Rico: An Exploratory Study. *Journal of Archaeological Science* 24:497-504.

–.
2003 Issues on the Diversity and Emergence of Middle-Rang Societies of the Ancient Caribbean: A Critique. *Journal of Archaeological Research* 11(1):1-42.

Cusick, James G.
1991 Culture Change and Ceramic Change in a Taíno Village. In *Proceedings of the Thirteenth International Congress for Caribbean Archaeology*, edited by E.N. Ayubi and J.B. Haviser, pp. 446-461. Archaeological-Anthropological Institute, Curaçao, Netherlands Antilles.

Deagan, Kathleen A. and José María Cruxent
2002a *Archaeology at La Isabela: America's First European Town*. Yale University Press, New Haven, CT.

–.
2002b *Columbus's Outpost among the Taínos: Spain and America at La Isabela, 1493-1498*. Yale University Press, New Haven, CT.

–.
1993 From Contact to *Criollos*: The Archaeology of Spanish Colonization in Hispaniola. *Proceedings of the British Academy* 81:67-104.

Deal, Michael
1990 Exploratory Analysis of Food Residues from Prehistoric Pottery and Other Artifacts from Eastern Canada. *S.A.S. Bulletin* 13(1):6-12.

Deal, Michael, June Morton and Ellen Foulkes
1991 The Role of Ceramic among the Prehistoric Hunter-Gatherers of the Maine-Maritimes Region: A View from the New Brunswick Interior. In *Prehistoric Archaeology in the Maritime Provinces: Past and Present Research*, edited by Michael Deal and Susan Blair. Reports in Archaeology No. 8. The Council of Maritime Premieres Maritime Committee on Archaeological Cooperation, Frederickton, New Brunswick.

Deal, Michael and Peter Silk
1988 Absorption Residues and Vessel Function: A Case Study from the Maine-Maritimes Region. In *A Pot for All Reasons: Ceramic Ecology Revisited*, edited by Charles C. Kolb and Louana M. Lackey, pp. 105-125. Ceramic de Cultura Maya et al., Philadelphia, PA.

Dor-Ner, Zvi and William Scheller
1991 *Columbus and the Age of Discovery*. William Morrow and Company, New York.

Dudd, Stephanie N. and Richard P. Evershed
1998 Direct Demonstration of Milk as an Element of Archaeological Economies. *Science* 282:1478-1481.

Dudd, Stephanie N., Richard P. Evershed and Alex M. Gibson
1999 Evidence for Varying Patterns of Exploitation of Animal Products in Different Prehistoric Pottery Traditions Based on Lipids Preserved in Surface and Absorbed Residues. *Journal of Archaeological Science* 26(12):1473-1482.

Dudd, Stephanie N., Martine Regert and Richard P. Evershed
1998 Assessing Microbial Lipid Contributions During Laboratory Degradations of Fats and Oils and Pure Triacylglycerols Absorbed in Ceramic Potsherds. *Organic Geochemistry* 29(5-7):1345-1354.

Dufour, Darna L.
2003 Cassava. In *Encyclopedia of Food and Culture*, edited by Solomon H. Katz, pp. 326-331. vol. 1. Charles Scribner's Sons, New York.

Eerkens, Jelmer W.
2001 *The Origins of Pottery among Late Prehistoric Hunter-Gatherers in California and the Western Great Basin.* Ph.D. dissertation, Department of Anthropology, University of California, Santa Barbara.

–.
2002 The Preservation and Identification of Piñon Resins by GC-MS in Pottery from the Western Great Basin. *Archaeometry* 44(1):95-105.

–.
2005 GC-MS Analysis and Fatty Acid Ratios of Archaeological Potsherds from the Western Great Basin of North America. *Archaeometry* 47(1):83-102.

Eglinton, Geoffrey, Graham A. Logan, R.P. Ambler, J.J. Boon and W.R.K. Perizonius
1991 Molecular Preservation. *Philosophical Transactions: Biological Sciences* 333(1268):315-328.

Espenshade, Christopher T.
2000 Reconstructing Household Vessel Assemblages and Site Duration at an Early Ostionoid Site from South-Central Puerto Rico. *Journal of Caribbean Archaeology* 1:1-22.

Evans, K. and C. Heron
1993 Biomolecular Archaeology and Lipids. *World Archaeology* 25(1):74-93.

Evershed, R. P., C. Heron, S. Charters and L. J. Goad
1992 The Survival of Food Residues: New Methods of Analysis, Interpretation and Application. *Proceedings of the British Academy* 77:187-208.

Evershed, R. P., H. R. Mottram, S. N. Dudd, A. W. Stott, G. J. Lawrence, A.M. Gibson, A. Conner, P. W. Blinkhorn and V. Reeves
1997 New Criteria for the Identification of Animal Fats Preserved in Archaeological Pottery. *Naturwissenschaften* 84:402-406.

Evershed, Richard P.
1990 Lipids from Samples of Skin from Seven Dutch Bog Bodies: Preliminary Report. *Archaeometry* 32:139-153.

–.
1992 Chemical Composition of a Bog Adipocere. *Archaeometry* 34(253-265).

–.
1993a Advances in Silylation. In *Handbook of Derivatives for Chromatography*, edited by Karl Blau and John Halket. 2nd ed. John Wiley and Sons, Ltd., West Sussex, England.

–.
1993b Biomolecular Archaeology and Lipids. *World Archaeology* 25(1):74-93.

Evershed, Richard P., Stephanie Charters and Anita Quye
1995 Interpreting Lipid Residues in Archaeological Ceramics: Preliminary Results from Laboratory Simulations of Vessel Use and Burial. *Material Issues in Art and Archaeology* 4(352):85-95.

Evershed, Richard P., Stephanie N. Dudd, Virginia R. Anderson-Stojanovic and Elizabeth R. Gebhard
2003 New Chemical Evidence for the Use of Combed Ware Pottery Vessels as Beehives in Ancient Greece. *Journal of Archaeological Science* 30(1):1-12.

Evershed, Richard P., Stephanie N. Dudd, Stephanie Charters, Hazel Mottram, Andrew W. Stott, Anthony Raven, Pim F. Van Bergen and Helen A. Bland
1999 Lipids as Carriers of Anthropogenic Signals from Prehistory. *Philosophical Transactions: Biological Sciences* 354:19-31.

Evershed, Richard P., Carl Heron and L. John Goad
1990 Analysis of Organic Residues of Archaeological Origin by High-Temperature Gas Chromatography and Gas Chromatography-Mass Spectrometry. *Analyst* 115:1339-1342.

Evershed, Richard P., Andrew W. Stott, Anthony Raven, Stephanie N. Dudd, Stephanie Charters and Ann Leyden
1995 Formation of Long-Chain Ketones in Ancient Pottery Vessels by Pyrolysis of Acyl Lipids. *Tetrahedron Letters* 36(48):8875-8878.

Ewen, Charles R.
2000 From Colonist to Creole: Archaeological Patterns of Spanish Colonization in the New World. *Historical Archaeology* 34(3):36-45.

Ferbel, P.J.
2002 Not Everyone Who Speaks Spanish Is from Spain: Taíno Survival in the 21st Century Dominican Republic. *KACIKE: The Journal of Caribbean Amerindian History and Anthropology* Special Issue. http://www.kacike.org/FerbelEnglish.pdf.

Fernández-Armesto, Felipe
1974 *Columbus and the Conquest of the Impossible*. Saturday Review Press, New York.

–.
2002 *Near a Thousand Tables: A History of Food*. The Free Press, New York.

Fewkes, Jesse Walter
1907 The Aborigines of Porto Rico and Neighboring Islands. *Twenty-fifth Annual Report of the US Bureau of Ethnology to the Secretary of the Smithsonian Institution* 1903-1904:17-89.

Floyd, Troy S.
1973 *The Columbian Dynasty in the Caribbean, 1492-1526*. University of New Mexico Press, Albuquerque.

Fortuna, Luis
1978 Analisis Polinico de Sanate Abajo. *Boletín del Museo del Hombre Dominicano* 10:125-130.

Frankel, E.N.
1980 Lipid Oxidation. *Progress in Lipid Research* 19:1-22.

Fukushima, K., S. Yamamoto, M. Uzaki, S. Morinaga and R. Ishiwatari
1987 Characterization of the Microbial Degradation Products of a Submerged Plant with Particular Reference to the Production of the Kerogen-Like Material. *Chemical Geology* 64(169-179).

García Arévalo, Manuel
1992 *Altos de Chavón Museo Arqueológico Regional Catálogo Conmemorativo V Centenario*. Amigo del Hogar, Santo Domingo, Dominican Republic.

Garton, G.A., W.R.H. Duncan and E.H. McEwan
1971 Composition of Adipose Tissue Triglycerides of the Elk (*Cervus Canadensis*), Caribou (*Rangifer Tarrandus Groenlandicus*), Moose (*Alces Alces*), and White-Tailed Deer (*Odocoileus Virginianus*). *Canadian Journal of Zoology* 49:1159-1162.

Goggin, John M.
1968 *Spanish Majolica in the New World*. Yale University Publications in Anthropology, 72. Yale University Press, New Haven.

Guitar, Lynne
1998 *Cultural Genesis: Relationships among Indians, Africans, and Spaniards in Rural Hispaniola, First Half of the Sixteenth Century.* Ph.D. dissertation, Department of History, Vanderbilt University.

Gurr, Michael I., John L. Harwood and Keith N. Frayn
2002 *Lipid Biochemistry*. 5th ed. Blackwell Science, Oxford, UK.

Hansel, Fabricio A., Mark S. Copley, Luiz A. S. Madureira and Richard P. Evershed
2004 Thermally Produced Ω-(O-Alkylphenyl)Alkanoic Acids Provide Evidence for the Processing of Marine Products in Archaeological Pottery Vessels. *Tetrahedron Letters* 45(14):2999-3002.

Harris, Marvin
1987 Foodways: Historical Overview and Theoretical Prolegomenon. In *Food and Evolution: Toward a Theory of Human Food Habits*, edited by Marvin Harris and Eric B. Ross, pp. 57-90. Temple University Press, Philadelphia.

Hedges, S. Blair
2001 Biogeography of the West Indies: An Overview. In *Biogeography of the West Indies: Patterns and Perspectives*, edited by Charles A. Woods and Florence E. Sergile, pp. 15-33. 2nd ed. CRC Press, Boca Raton, FL.

Hermann, M. and J. Heller
1997 Andean Roots and Tubers at the Crossroads. *Promoting the conservation and use of underutilized and neglected crops* 21. http://www.ipgri.cgiar.org/publications/pubfile.asp?ID_PUB=472.

Heron, C., R. P. Evershed and L. J. Goad
1991 Effects of Migration of Soil Lipids on Organic Residues Associated with Buried Potsherds. *Journal of Archaeological Science* 18(6):641-659.

Heron, Carl and Richard P. Evershed
1993 The Analysis of Organic Residues and the Study of Pottery Use. In *Archaeological Theory and Method*, edited by Michael B. Schiffer, pp. 247-284. University of Arizona Press, Tucson.

Hildritch, T.P. and P.N. Williams
1964 *The Chemical Composition of Natural Fats*. John Wiley and Sons, New York.

Hill, H.E. and J. Evans
1989 Crops of the Pacific: New Evidence from the Chemical Analysis of Organic Residues in Pottery. In *Foraging and Farming: The Evolution of Plant Exploitation*, edited by D.R. Harris and G.C. Hillman, pp. 418-425. Unwin Hyman Ltd., London.

Hocart, C.H., B. Fankhauser and D.W. Buckle
1993 Chemical Archaeology of Kava, a Potent Brew. *Rapid Communications in Mass Spectrometry* 7:219-224.

Hudlickey, M.
1990 *Oxidations in Organic Chemistry*. American Chemical Society, Washington, DC.

Hurst, W. Jeffrey, Robert A. Martin, Jr., Stanley M. Tarka, Jr. and Grant D. Hall
1989 Authentication of Cocoa in Maya Vessels Using High-Performance Liquid Chromatographic Techniques. *Journal of Chromatography* 466:279-289.

Joseph, Garnette
1997 Five Hundred Years of Indigenous Resistance. In *The Indigenous Peoples of the Caribbean*, edited by Samuel M. Wilson, pp. 215-222. University of Florida Press, Gainesville.

Keegan, William F.
1986 The Ecology of Lucayan Arawak Fishing Practices. *American Antiquity* 51:816-825.

–.
1992 *The People Who Discovered Columbus: The Prehistory of the Bahamas*. University of Florida Press, Gainesville.

–.
1996 West Indian Archaeology 2: After Columbus. *Journal of Archaeological Research* 4:265-294.

–.
1997 *Bahamian Archaeology: Life in the Bahamas and Turks and Caicos before Columbus*. Media Publishing, Nassau.

–.
2000 The Caribbean, Including Northern South America and Lowland Central America: Early History. In *Cambridge World History of Food*, edited by Kenneth F. Kiple and Kriemhild Coneè Ornelas, pp. 1260-1278. vol. 2. Cambridge University Press, Cambridge.

Keegan, William F. and Michael J. DeNiro
1988 Stable Carbon- and Nitrogen-Isotope Ratios of Bone Collagen Used to Study Coral-Reef and Terrestrial Components of Prehistoric Bahamian Diet. *American Antiquity* 53(2):320-336.

Keegan, William F., Roger W. Portell and John Slapcinsky
2003 Changes in Invertebrate Taxa at Two Pre-Columbian Sites in Southwestern Jamaica, A.D. 800-1500. *Journal of Archaeological Science* 30:1607-1617.

Kharbade, B.V. and G.P. Joshi
1995 Thin-Layer Chromatographic and Hydrolysis Method for the Identification of Plant Gums in Art Objects. *Studies in Conservation* 40:93-102.

Kimpe, K., C. Drybooms, E. Schrevens, P. A. Jacobs, R. Degeest and M. Waelkens
2004 Assessing the Relationship between Form and Use of Different Kinds of Pottery from the Archaeological Site Sagalassos (Southwest Turkey) with Lipid Analysis. *Journal of Archaeological Science* 31(11):1503-1510.

Kimpe, K., P. A. Jacobs and M. Waelkens
2002 Mass Spectrometric Methods Prove the Use of Beeswax and Ruminant Fat in Late Roman Cooking Pots. *Journal of Chromatography A* 968(1-2):151-160.

King, Steven and Liliana Campos Dudley
1991 Nature's Future. In *Seeds of Change: Five Hundred Years since Columbus*, edited by Herman J. Viola and Carolyn Margolis, pp. 249-263. Smithsonian Institution Press, Washington, DC.

Lalueza-Fox, Carlos, Francisco Luna Calderón, Frances Calafell, B. Morera and Jamie Bertranpetit
2001 MtDNA from Extinct Taínos and the Peopling of the Caribbean. *Annals of Human Genetics* 65(2):137-151.

Las Casas, Bartolomé de
1989 *The Diario of Christopher Columbus's First Voyage to America, 1492-1493*. Translated by Oliver Dunn and James E. Kelley, Jr. University of Oklahoma Press, Norman.

Leví-Strauss, Claude
1963 *Totemism*. Beacon Press, Boston.

Lister, Florence C. and Robert H. Lister
1987 *Andalusian Ceramics in Spain and New Spain*. University of Arizona Press, Tucson.

Lyon, Eugene
1989 *Niña,* Ship of Discovery. In *First Encounters: Spanish Explorations in the Caribbean and the United States, 1492-1570*, edited by Jerald T. Milanich and Susan Milbrath, pp. 55-65. University of Florida Press, Gainesville.

Malainey, M.E., R. Przybylski and B.L. Sherriff
1999a The Effects of Thermal and Oxidative Degradation on the Fatty Acid Composition of Food Plants and Animals of Western Canada: Implications for the Identification of Archaeological Vessel Residues. *Journal of Archaeological Science* 26:95-103.

–.
1999b Identifying the Former Contents of Late Precontact Period Pottery Vessels from Western Canada Using Gas Chromatography. *Journal of Archaeological Science* 26:425-438.

Malainey, Mary Evelyn
1997 *The Reconstruction and Testing of Subsistence and Settlement Strategies for the Plains, Parkland and Southern Boreal Forest.* Ph.D. dissertation, Department of Anthropology, University of Manitoba.

Marchbanks, Michael Lee
1989 *Lipid Analysis in Archaeology: An Initial Study of Ceramics and Subsistence at the George C. Davis Site.* Master's thesis, University of Texas.

Marken, Mitchell W.
1994 *Pottery from Spanish Shipwrecks, 1500-1800*. University Press of Florida, Gainesville.

Martyr D'Anghiera, Peter
1989 *Décades del Nuevo Mundo*. Translated by A. Millares Carlo. Sociedad Dominicano de Bibliófilos, Santo Domingo.

McEwan, Bonnie G.
1995 Spanish Precedents and Domestic Life at Puerto Real: The Archaeology of Two Spanish Homesites. In *Puerto Real: The Archaeology of a Sixteenth-Century Spanish Town*, edited by Kathleen Deagan, pp. 197-229. University Press of Florida, Tallahassee.

McNeill, William H.
1991 American Food Crops in the Old World. In *Seeds of Change: A Quincentennial Commemoration*, edited by Herman J. Viola and Carolyn Margolis, pp. 43-59. Smithsonian Institution Press, Washington, DC.

Meiggs, R.
1982 *Trees and Timber in the Ancient Mediterranean World*. Clarendon, Oxford.

Miller, George R. and Richard L. Burger
1995 Our Father the Caymen, Our Dinner the Llama: Animal Utilization at Chavín De Huantar, Peru. *American Antiquity* 60(3):421-458.

Morgan, E.D., L. Titus, R.J. Small and C. Edwards
1983 Gas Chromatographic Analysis of Fatty Material from a Thule Midden. *Archaeometry* 26(43-48).

Morison, Samuel
1942 *Admiral of the Ocean Sea*. Little, Brown, Boston.

Mottram, H. R., S. N. Dudd, G. J. Lawrence, A. W. Stott and R. P. Evershed
1999 New Chromatographic, Mass Spectrometric and Stable Isotope Approaches to the Classification of Degraded Animal Fats Preserved in Archaeological Pottery. *Journal of Chromatography A* 833(2):209-221.

Moya Pons, Frank
1992 The Politics of Forced Indian Labor in La Española. *Antiquity* 66(250):130-139.

–.
1998 *The Dominican Republic: A National History*. Markus Wiener Publishers, Inc., Princeton, NJ.

Newsom, Lee A. and Elizabeth S. Wing
2004 *On Land and Sea: Native American Uses of Biological Resources in the West Indies*. University of Alabama Press, Tuscaloosa.

Newsom, Lee Ann
1993 *Plant Use by Saladoid and Taíno People of the Caribbean.* Ph.D. dissertation, Department of Anthropology, University of Florida.

Ober, Frederick
1893 *In the Wake of Columbus: Adventures of the Special Commissioner Sent by the World's Columbian Exposition to the West Indies*. D. Lothrop, Boston.

Olazagasti, Ignacio
1997 The Material Culture of the Taíno Indians. In *The Indigenous People of the Caribbean*, edited by Samuel M. Wilson, pp. 131-139. University Press of Florida, Gainesville.

Ortega, Elpidio
1980 *Introduccion a la Loza Comun o Alfareria en el Periodo Colonial de Santo Domingo*. Fundacion Ortega Alvarez Serie Cientifica III. Fundacion Ortega Alvarez, Inc., Santo Domingo, Dominican Republic.

–.
1988 *La Isabela y la Arqueologia en la Ruta de Colón*. Universidad Central del Este, San Pedro de Macoris, Dominican Republic.

Oudemans, T.F.M. and J.J. Boon
1991 Molecular Archaeology: Analysis of Charred (Food) Remains from Prehistoric Pottery by Pyrolysis-Gas Chromatography/Mass Spectrometry. *Journal of Analytical and Applied Pyrolysis* 20:197-227.

Oviedo, Gonzalo Fernández de
1959 *Natural History of the West Indies*. Translated by Sterling A. Stoudemire. University of North Carolina Press, Chapel Hill.

Palms, Erwin W.
1945 Excavations of La Isabela: White Man's First Town in the Americas. *Acta Americana* 3:298-303.

Pané, Ramón
1999 *An Account of the Antiquities of the Indians*. Translated by Susan C. Griswold and with introduction and notes by José Juan Arrom. Latin America in Translation/En Traducción/Em Tradução. Duke University Press, Durham.

Patrick, M., A.J. de Koning and A.B. Smith
1985 Gas Chromatographic Analysis of Fatty Acids in Food Residues from Ceramics Found in the Southwestern Cape, South Africa. *Archaeometry* 27:231-236.

Pérez-Mallaína, Pablo E.
1998 *Spain's Men of the Sea: Daily Life on the Indies Fleets in the Sixteenth Century*. Translated by Carla Rahn Phillips. The Johns Hopkins University Press, Baltimore.

Rafferty, Sean M.
2002 Identification of Nicotine by Gas Chromatography/Mass Spectrometry Analysis of Smoking Pipe Residue. *Journal of Archaeological Science* 29:897-907.

Raven, A. M., P. F. van Bergen, A. W. Stott, S. N. Dudd and R. P. Evershed
1997 Formation of Long-Chain Ketones in Archaeological Pottery Vessels by Pyrolysis of Acyl Lipids. *Journal of Analytical and Applied Pyrolysis* 40-41:267-285.

Reber, E.A. and R. P. Evershed
2004 How Did Mississippians Prepare Maize? The Application of Compound-Specific Carbon Isotope Analysis to Absorbed Pottery Residues from Several Mississippi Valley Sites. *Archaeometry* 46:19-33.

Reber, Eleanora A.
2001 *Maize Detection in Absorbed Pottery Residues: Development and Archaeological Application.* Ph.D. dissertation, Department of Anthropology, Harvard University.

Reber, Eleanora A., Stephanie N. Dudd, Nikolaas J. van der Merwe and Richard P. Evershed
2004 Direct Detection of Maize in Pottery Residues Via Compound Specific Stable Carbon Isotope Analysis. *Antiquity* 78(301):682-691.

Regert, M., S. Colinart, L. Degrand and O. Decavallas
2001 Chemical Alteration and Use of Beeswax through Time: Accelerated Ageing Tests and Analysis of Archaeological Samples from Various Environmental Contexts. *Archaeometry* 43:549-569.

Regert, M., S. Vacher, C. Moulherat and O. Decavallas
2003 Adhesive Production and Pottery Function During the Iron Age at the Site of Grand Aunay (Sarthe, France). *Archaeometry* 45(1):101-120.

Regert, Martine, Helen A. Bland, Stephanie N. Dudd, Pim F. van Bergen and Richard P. Evershed
1998 Free and Bound Fatty Acid Oxidation Products in Archaeological Ceramic Vessels. *Proceedings of the Royal Society of London B* 265:2027-2032.

Reitz, Elizabeth J. and C. Margaret Scarry
1985 *Reconstructing Historic Subsistence with an Example from Sixteenth-Century Spanish Florida*. SHA Special Publication Series, No. 3. Society for Historical Archaeology, Rockville, MD.

Rhee, K.S.
1992 Fatty Acids in Meats and Meat Products. In *Fatty Acids in Foods and Their Health Implications*, edited by C.K. Chow, pp. 65-94. Marcel Dekker, New York.

Rice, Patricia M.
1987 *Pottery Analysis: A Sourcebook*. University of Chicago Press, Chicago.

–.
1996 Recent Ceramic Analysis: 1. Function, Style, Origins. *Journal of Archaeological Research* 4:133-163.

Robinson, Neil, Richard P. Evershed, W. James Higgs, Katherine Jerman and Geoffrey Eglinton
1987 Proof of a Pine Wood Origin for Pitch from Tudor (Mary Rose) and Etruscan Shipwrecks: Application of Analytical Organic Chemistry in Archaeology. *Analyst* 112:637-644.

Rodríguez-Alegría, Enrique
2005 Eating Like an Indian: Negotiating Social Relations in the Spanish Colonies. *Current Anthropology* 46(4):551-573.

Roosevelt, Anna C.
1980 *Parmana: Prehistoric Maize and Manioc Subsistence among the Amazon and Orinoco*. Academic Press, New York.

–.
1987 The Evolution of Human Subsistence. In *Food and Evolution: Toward a Theory of Human Food Habits*, edited by Marvin Harris and Eric B. Ross, pp. 565-578. Temple University Press, Philadelphia.

Rosen, Baruch, Ehud Galili and Jacob Sharvit
2001 Traces of Fatty Acids from a Byzantine Sounding Lead Recovered Off the Israeli Coast. *Journal of Archaeological Science* 28:1323-1327.

Rottländer, Rolf C.A
1990 Lipid Analysis in the Identification of Vessel Contents. *MASCA Research Papers in Science and Archaeology* 7:37-40.

Rouse, Irving
1987 Whom Did Columbus Discover in the West Indies. *American Archaeology* 6:85-88.

–.
1992 *The Taínos: Rise and Decline of the People Who Greeted Columbus*. Yale University Press, New Haven, CT.

Russ, G.R.
1991 Coral Reef Fisheries: Effects and Yields. In *The Ecology of Fishes on Coral Reefs*, edited by P.F. Sale, pp. 601-635. Academic Press, San Diego.

Sauer, Carl Ortwin
1966 *The Early Spanish Main*. University of California Press, Berkeley.

Shackley, Mara
1982 Gas Chromatographic Identification of a Resinous Deposit from a 6th Century Storage Jar and Its Possible Identification. *Journal of Archaeological Science* 9:305-306.

Sherriff, B. L., M.A. Tisdale, B.G. Sayer, H.P. Schwarcz and M. Knyf
1975 Nuclear Magnetic Resonance Spectroscopy and Isotope Analysis of Carbonized Residues from Subartic Canadian Prehistoric Pottery. *Archaeometry* 17:95-111.

Skibo, James M.
1992 *Pottery Function: A Use-Alteration Perspective*. Plenum Press, New York.

Skibo, James M. and Michael Deal
1995 Pottery Function and Organic Residue: An Appraisal. In *Conference on Archaeology in Southeast Asia*, edited by C. Yeung and W.B. Li, pp. 319-329. University Museum and Art Gallery, Hong Kong.

Smith, C.R.
1970 Occurrence of Unusual Fatty Acids in Plants. *Progress in the Chemistry of Fats and Other Lipids* 11:137-177.

Sørenson, M.L.S.
2000 *Gender Archaeology*. Malden, MA, Polity Press.

Stacey, R.J., C.R. Cartwright and C. McEwan
2006 Chemical Characterization of Ancient Mesoamerican 'Copal' Resins: Preliminary Results. *Archaeometry* 48(2):323-340.

Stern, B., C. Heron, L. Corr, M. Serpico and J. Bourriau
2003 Compositional Variations in Aged and Heated Pistacia Resin Found in Late Bronze Age Canaanite Amphorae and Bowls from Amarna, Egypt. *Archaeometry* 45:457-469.

Stern, B., C. Heron, M. Serpico and J. Bourriau
2000 A Comparison of Methods for Establishing Fatty Acid Concentration Gradients across Potsherds: A Case Study Using Late Bronze Age Canaanite Amphorae. *Archaeometry* 42(2):399-414.

Sturtevant, William C.
1961 Taíno Agriculture. *Anthropologica Supplement* 2:69-82.

Todorov, Tzvetan
1984 *The Conquest of America: The Question of the Other*. Translated by Richard Howard. Harper & Row, New York.

Tripp, Jennifer A. and Robert E.M. Hedges
2004 Single-Compound Isotopic Analysis of Organic Materials in Archaeology. *LCGC North America* 22(11):1098-1106.

Tuross, Noreen, Marilyn L. Fogel, Lee Newsom and Glen H. Doran
1994 Subsistence in the Florida Archaic: The Stable-Isotope and Archaeobotanical Evidence from the Windover Site. *American Antiquity* 59(2):288-303.

Tykot, R.H., N.J. van der Merwe and N. Hammond
1996 Stable Isotope Analysis of Bone Collagen, Bone Apatite, and Tooth Enamel in the Reconstruction of Human Diet: A Case Study from Cuello, Belize. In *Archaeological Chemistry: Organic, Inorganic, and Biochemical Analysis*, edited by Mary Virginia Orna, pp. 355-365. A.C.S. Symposium Series, No. 625. American Chemical Society, Washington, DC.

van den Berg, K.J., J.J. Boon, I. Pastorova and L.F.M. Spetter
2000 Mass Spectrometric Methodology for the Analysis of Highly Oxidised Diterpenoid Acids in Old Master Paintings. *Journal of Mass Spectrometry* 35:512-533.

VanderVeen, James M.
2005a El Reconocimiento Arqueológico de la Regíon de Bahía Isabela. *Boletín del Museo del Hombre Dominicano* 39:43-47.

–.
2005b Registro de Unidades y Muestras Recogidas del Tamarindo. Manuscript on file, Museo del Hombre Dominicano, Santo Domingo, Dominican Republic.

VanderVeen, James M. and Geoffrey W. Conrad
2002 La Examinación Arqueológica en la Rosa de Bayahibe. Manuscript on file, Museo del Hombre Dominicano, Santo Domingo, Dominican Republic.

Veloz Maggiolo, Marcio
1997 The Daily Life of the Taíno People. In *Taíno: Pre-Columbian Art and Culture from the Caribbean*, edited by Fatima Bercht, Estrellita Brodsky, John Alan Farmer and Dicey Taylor, pp. 34-45. Monacelli Press, New York.

Veloz Maggiolo, Marcio and Elpidio Ortega
1980 Nuevos Hallazgos Arqueológicos en la Costa Norte de Santo Domingo. *Boletín del Museo del Hombre Dominicano* 9:11-48.

Viola, Herman J.
1991 Seeds of Change. In *Seeds of Change: A Quincentennial Commemoration*, edited by Herman J. Viola and Carolyn Margolis, pp. 11-16. Smithsonian Institution Press, Washington, DC.

West, Robert C.
1989 Physical Patterns of Middle America. In *Middle America: Its Lands and Peoples*, edited by Robert C. West and John P. Augelli, pp. 23-59. 3rd ed. Prentice-Hall, Inc., Englewood Cliffs, NJ.

White, C.D, D.M. Pendergast, F.J. Longstaffe and K.R. Law
2001 Social Complexity and Food Systems at Altun Ha, Belize: The Isotopic Evidence. *Latin American Antiquity* 12:371-393.

White, Jennifer L. and Ross D.E. MacPhee
2001 The Sloths of the West Indies: A Systematic and Phylogenetic Review. In *Biogeography of the West Indies: Patterns and Perspectives*, edited by Charles A. Woods and Florence E. Sergile, pp. 201-236. 2nd ed. CRC Press, Boca Raton, FL.

Wilk, Richard R.
1999 "Real Belizean Food": Building a Local Identity in the Transnational Caribbean. *American Anthropologist* 101(2):244-255.

Wilson, Samuel M.
1990 *Hispaniola: Caribbean Chiefdoms in the Age of Columbus*. University of Alabama Press, Tuscaloosa.

–.
1997a The Caribbean before European Conquest: A Chronology. In *Taíno: Pre-Columbian Art and Culture from the Caribbean*, edited by Fatima Bercht, Estrellita Brodsky, John Alan Farmer and Dicey Taylor, pp. 15-17. Monacelli Press, New York.

–.
1997b The Legacy of the Indigenous People of the Caribbean. In *The Indigenous People of the Caribbean*, edited by Samuel M. Wilson, pp. 206-213. University Press of Florida, Gainesville.

Wing, Elizabeth S.
1974 Factors Influencing Exploitation of Marine Resources. In *The Sea in the Pre-Columbian World: A Conference at Dumbarton Oaks*, edited by Elizabeth P. Benson, pp. 47-66. Dumberton Oaks Research Library and Collections, Washington, DC.

–.
2001 Native American Use of Animals in the Caribbean. In *Biogeography of the West Indies: Patterns and Perspectives*, edited by Charles A. Woods and Florence E. Sergile, pp. 481-518. 2nd ed. CRC Press, Boca Raton, FL.

Wing, Elizabeth S. and Elizabeth J. Reitz
1982 Prehistoric Fishing Communities of the Caribbean. *Journal of New World Archaeology* 5:13-32.

Wing, S.R. and E.S. Wing
2001 Prehistoric Fisheries in the Caribbean. *Coral Reefs* 20:1-8.

Wright, Irene A. (editor)
1929 *Spanish Documents Concerning English Voyages to the Caribbean, 1527-1568: Selected from the Archives of the Indies at Seville.* Hakluyt Society, London.

APPENDIX A:

DESCRIPTION OF ARCHAEOLOGICAL SAMPLES

Sample ID	*Culture*	*Decoration*	*Vessel Form*	*Vessel Area*	*Paste Color*	*Temper*	*Context*
CO 01	indigenous	undecorated	burén	rim/body	7.5YR 6/4	grit	excavated
CO 02	indigenous	Chicoid	bowl	shoulder	7.5YR 6/3	grit	excavated
CO 03	indigenous	undecorated	unknown	body	7.5YR 5/4	grit	excavated
ECZ 01	indigenous	undecorated	bowl	body	7.5YR 5/3	grit	surface
ECZ 02	indigenous	undecorated	bowl	body	10YR 5/2	grit	surface
ECZ 03	indigenous	undecorated	bowl	body	7.5YR 5/4	grit	surface
ECZ 04	indigenous	undecorated	unknown	shoulder	10YR 4/2	grit	surface
ECZ 05	indigenous	undecorated	unknown	shoulder	10YR 4/2	grit	surface
ECZ 06	indigenous	undecorated	unknown	shoulder	10YR 4/1	grit	surface
ECZ 09	indigenous	Meillacan	jar	shoulder	7.5YR 5/3	grit	surface
ECZ 10	indigenous	Meillacan	jar	shoulder	7.5YR 5/3	grit	surface
ECZ 11	indigenous	Meillacan	jar	shoulder	10YR 5/3	grit	surface
ECZ 12	indigenous	undecorated	jar	body	10YR 4/1	grit	surface
ECZ 13	indigenous	undecorated	jar	body	10YR 4/1	grit	surface
ECZ 14	indigenous	undecorated	jar	body	10YR 4/1	grit	surface
ES 01	indigenous	undecorated	bowl	base	7.5YR 6/6	shell mix	excavated
ES 02	indigenous	Chicoid	bowl	shoulder	10YR 4/1	grit	excavated
ES 04	indigenous	Chicoid	bowl	shoulder	10YR 3/1	grit	excavated
ES 05	indigenous	Meillacan	bowl	shoulder	10YR 4/3	grit	excavated
ES 06	indigenous	Meillacan	bowl	shoulder	10YR 6/2	grit	excavated
ES 07	indigenous	Meillacan	bowl	rim	10YR 6/2	grit	excavated
ES 08	indigenous	Meillacan	bowl	rim	10YR 4/2	grit	excavated
HM 01	indigenous	undecorated	unknown	base	7.5YR 5/4	shell mix	submerged
HM 02	indigenous	undecorated	bowl	shoulder	10YR 5/3	shell mix	submerged
HM 03	indigenous	undecorated	jar	neck	10YR 5/2	grit	submerged
ISA 01	Columbian	undecorated	unknown	shoulder	7.5YR 5/6	grit	curated
ISA 02	Columbian	undecorated	canteen	body	7.5YR 6/4	grit	curated
ISA 03a	Columbian	undecorated	jar	rim/shoulder	7.5YR 7/4	grit	curated
ISA 03b	Columbian	undecorated	jar	rim/shoulder	7.5YR 7/4	grit	curated
ISA 04	Columbian	incised	jar	neck	5YR 4/6	grit	curated
ISA 05	Columbian	undecorated	bowl	body	7.5YR 6/2	grit	curated
ISA 07	Columbian	incised	bowl	rim	7.5YR 5/6	grit	curated
ISA 08	Columbian	undecorated	dish	base	7.5YR 6/6	grit	curated
ISA 09	Columbian	incised	jar	rim/shoulder	5YR 5/6	grit	curated
ISA 10	Columbian	undecorated	unknown	body	5YR 5/2	grit	curated
ISA 11	Columbian	ridged	jar	neck	5YR 6/6	grit	curated
ISA 12	Columbian	undecorated	jar	rim/shoulder	5YR 6/3	grit	curated
ISA 13	Columbian	ridged	jar	rim/shoulder	5YR 5/6	grit	curated
ISA 14	Columbian	incised	unknown	body	not msrd	not msrd	curated
ISA 15	Columbian	cord-marked	bowl	rim	5YR 4/2	grit	curated
ISA 16	indigenous	undecorated	unknown	body	5YR 5/2	grit	curated

Sample ID	*Culture*	*Decoration*	*Vessel Form*	*Vessel Area*	*Paste Color*	*Temper*	*Context*
ISA 17	indigenous	undecorated	bowl	body	5YR 5/2	grit	Curated
ISA 18	Columbian	ridged	jar	rim/shoulder	5YR 5/4	grit	curated
ISA 21	Columbian	undecorated	bowl	base	5YR 4/6	grit	curated
ISA 22	Columbian	undecorated	plato	rim/base	5YR 6/4	grit	curated
ISA 23	Columbian	incised/ridged	jar	neck	5YR 6/8	grit	curated
ISA 23a	Columbian	incised/ridged	jar	neck	5YR 6/8	grit	curated
ISA 23b	Columbian	incised/ridged	jar	neck	5YR 6/8	grit	curated
ISA 24	Columbian	incised/ridged	jar	rim	5YR 6/2	grit	curated
ISA 25	Columbian	undecorated	unknown	body	5YR 5/8	grit	curated
ISA 28	Columbian	undecorated	unknown	body	5YR 4/1	grit	curated
ISA 29	Columbian	undecorated	bowl	body	5YR 3/1	grit	curated
ISA 30a	indigenous	undecorated	burén	body	5YR 5/3	grit	curated
ISA 30b	indigenous	undecorated	burén	body	5YR 5/3	grit	curated
ISA 31	Columbian	with handle	bowl	rim	5YR 5/6	grit	curated
ISA 32	Columbian	undecorated	unknown	body	5YR 5/6	grit	curated
LEO 01	indigenous	Meillacan	bowl	body	10YR 4/2	grit	surface
LEO 02	indigenous	Meillacan	bowl	body	10YR 4/2	grit	surface
LEO 03	indigenous	undecorated	jar	rim/shoulder	10YR 4/2	grit	surface
LEO 04	indigenous	undecorated	jar	rim/shoulder	10YR 4/2	grit	surface
PER 01	indigenous	undecorated	unknown	rim	10YR 4/2	grit	surface
PER 02	indigenous	Meillacan	bowl	body	10YR 5/1	grit	surface
PER 03	indigenous	undecorated	jar	rim/shoulder	10YR 4/1	grit	surface
PER 04	indigenous	undecorated	jar	body	10YR 4/2	grit	surface
PER 05	indigenous	Chicoid	bowl	rim/shoulder	10YR 6/3	grit	surface
PER 06	indigenous	undecorated	bowl	body	10YR 4/1	grit	surface
PM 01	indigenous	Chicoid	bowl	rim/body	10YR 5/3	grit	excavated
PM 02	indigenous	undecorated	bowl	rim/shoulder	7.5YR 4/4	shell mix	excavated
TAM 01	indigenous	Chicoid	bowl	rim	7.5YR 4/6	grit	excavated
TAM 02	indigenous	Chicoid	bowl	body	7.5YR 4/6	grit	excavated
TAM 03	indigenous	undecorated	bowl	body	7.5YR 3/3	grit	excavated
TAM 04	indigenous	undecorated	unknown	body	10YR 3/4	grit	excavated
TAM 05	indigenous	Chicoid	jar	rim	10YR 4/4	grit	excavated
TAM 07	indigenous	incised	unknown	body	10YR 5/2	grit	excavated
TAM 08	indigenous	Chicoid	unknown	body	10YR 5/2	grit	excavated
TAM 09	indigenous	Chicoid	unknown	body	7.5YR 5/2	grit	excavated
TAM 10	indigenous	Chicoid	bowl	body	7.5YR 4/2	grit	excavated
TAM 11	indigenous	undecorated	bowl	body	7.5YR 4/2	grit	excavated
TAM 12	indigenous	undecorated	unknown	body	10YR 4/3	grit	excavated
TAM 14	indigenous	Meillacan	unknown	body	10YR 4/3	grit	excavated
TAM 15	indigenous	Meillacan	unknown	body	7.5YR 6/6	grit	excavated
TAM 16	indigenous	undecorated	bowl	body	7.5YR 4/2	grit	excavated
TAM 17	indigenous	undecorated	unknown	body	7.5YR 3/1	grit	excavated

Sample ID	*Culture*	*Decoration*	*Vessel Form*	*Vessel Area*	*Paste Color*	*Temper*	*Context*
TAM 18a	indigenous	undecorated	burén	rim/body	75.YR 5/4	grit	excavated
TAM 18b	indigenous	undecorated	burén	rim/body	7.5YR 5/4	grit	Excavated
TAM 19a	indigenous	undecorated	burén	rim/body	7.5YR 6/4	grit	excavated
TAM 19b	indigenous	undecorated	burén	rim/body	7.5YR 6/4	grit	excavated
TAM 21a	indigenous	undecorated	unknown	body	7.5YR 4/2	grit	excavated
TAM 21b	indigenous	undecorated	unknown	body	7.5YR 4/2	grit	excavated
TAM 22	indigenous	Meillacan	bowl	rim	7.5YR 5/3	grit	excavated
TAM 23a	indigenous	undecorated	bowl	body	7.5YR 3/2	shell mix	excavated
TAM 23b	indigenous	undecorated	bowl	body	7.5YR 3/2	shell mix	excavated
TAM 24	indigenous	Chicoid	bowl	rim	7.5YR 4/2	grit	excavated
TAM 25a	indigenous	undecorated	bowl	body	10YR 3/4	grit	excavated
TAM 25b	indigenous	undecorated	bowl	body	10YR 3/4	grit	excavated
TAM 25c	indigenous	undecorated	bowl	body	10YR 3/4	grit	excavated
TAM 26	indigenous	Meillacan	jar	neck	7.5YR 4/6	grit	excavated

Sample ID	*Color*	*Composition*	*Origin*	*Context*
CO 04	not msrd	soil	from sherd CO 01-03	excavated
ECZ 07	10YR 4/2	soil	from sherds ECZ 02, 05	surface
ECZ 08	10YR 6/1	soil	from sherds ECZ 03, 06	surface
ECZ 15	10 YR 6/1	soil	from Edilio Cruz site	surface
ES 09	not msrd	soil	from sherds ES 01-02	collected
ES 10	not msrd	soil	from sherds ES 04-08	collected
LEO 05	not msrd	soil	from sherds LEO 01-02	surface
LEO 06	not msrd	soil	from sherds LEO 03-04	surface
LEO 07	10YR 4/2	soil	from Loma de Leonardo site	surface
PER 07	10YR 6/2	soil	from sherds PER 01-06	surface
PM 03	not msrd	soil	from sherds PM 01-02	excavated
TAM 13	10YR 2/2	charcoal	from sherd TAM 12	excavated
TAM 27	7.5YR 4/4	soil	from sherds TAM 21-24	excavated
TAM 28	10YR 4/4	soil	from sherds TAM 25-26	excavated
TAM 29	10YR 2/2	charcoal	from sherd TAM 25	excavated

APPENDIX B:

CHARACTERISTICS OF SAMPLES SELECTED FOR ANALYSIS

ID	*Sample*	*Wt. (g)*	*TLE (mg)*	*R (µg/g)**	*Notes*
CO 01	sherd	44.2	0.0599	1.3552	
CO 02	sherd	19.6	0.0497	2.5383	
CO 03	sherd	20.0	0.0434	2.1700	
CO 04	soil	not msrd	0.0189	n/a	from CO 01-03
ECZ 01	sherd	15.0	0.0087	0.5800	steel bushed only
ECZ 02	sherd	15.0	0.0092	0.6133	same as above but rinsed with solvent
ECZ 03	sherd	15.0	0.0154	1.0267	same as above but washed with water
ECZ 04	sherd	15.0	0.0032	0.2133	steel brushed only
ECZ 05	sherd	15.0	0.0023	0.1533	same as above but rinsed with solvent
ECZ 06	sherd	15.0	0.0015	0.1000	same as above but washed with water
ECZ 07	soil	0.0	0.0016	207.7922	from ECZ 02, 05
ECZ 08	soil	0.4	0.0058	15.1436	from ECZ 03, 06
ECZ 09	sherd	15.0	0.0003	0.0200	no cleaning action taken
ECZ 10	sherd	15.0	0.0013	0.0867	same as above but steel brushed exterior
ECZ 11	sherd	15.0	0.0359	2.3933	same as above but steel brushed all
ECZ 12	sherd	15.0	0.0030	0.2000	no cleaning action taken
ECZ 13	sherd	15.0	0.0012	0.0800	same as above but steel brushed exterior
ECZ 14	sherd	15.0	0.0001	0.0067	same as above but steel brushed all
ECZ 15	soil	0.5	0.0007	1.5247	from site
ES 01	sherd	30.0	error	n/a	baked sherd blank
ES 02	sherd	30.0	error	n/a	
ES 03	chemicals	not msrd	error	n/a	solvent blank
ES 04	sherd	20.0	0.0291	1.4550	
ES 05	sherd	20.0	0.0029	0.1450	
ES 06	sherd	20.0	error	n/a	
ES 07	sherd	20.0	error	n/a	
ES 08	sherd	20.0	0.0053	0.2650	
ES 09	soil	not msrd	0.1847	n/a	from ES 01-02
ES 10	soil	not msrd	0.0008	n/a	from ES 04-08
HM 01	sherd	2.0	0.0983	49.1500	
HM 02	sherd	2.0	0.0983	49.1500	
HM 03	sherd	2.0	0.0058	2.9000	
ISA 01	sherd	15.2	0.0199	1.3092	
ISA 02	sherd	16.2	0.0234	1.4453	
ISA 03	sherd	15.1	0.0301	1.9921	
ISA 03b	sherd	15.0	0.0049	0.3267	re-analyzed above sherd
ISA 04	sherd	15.4	0.0337	2.1855	
ISA 05	sherd	15.5	0.0230	1.4829	
ISA 07	sherd	10.0	0.0104	1.0400	
ISA 08	sherd	15.0	0.0031	0.2067	
ISA 09	sherd	15.0	0.0150	1.0000	
ISA 10	sherd	15.0	0.0077	0.5133	
ISA 11	sherd	15.0	0.0125	0.8333	
ISA 12	sherd	13.4	0.0077	0.5735	baked sherd blank
ISA 13	sherd	10.0	0.0043	0.4300	sample in Teflon tube
ISA 14	sherd	3.8	n/a	n/a	sample lost prior to GC analysis
ISA 15	sherd	10.0	0.0172	1.7200	
ISA 16	sherd	10.0	0.0036	0.3600	

*R is the ratio of total lipid extract (TLE) in micrograms to sherd weight in grams.

ID	*Sample*	*Wt. (g)*	*TLE (mg)*	*R (ug/g)*	*Notes*
ISA 17	sherd	10.0	0.0018	0.1800	
ISA 18	sherd	10.0	0.0100	1.0000	ISA 13 in glass tube
ISA 19	chemicals	not msrd	0.0083	n/a	solvent blank in glass tube
ISA 20	chemicals	not msrd	0.0008	n/a	solvent blank in Teflon tube
ISA 21	sherd	15.0	0.0056	0.3733	
ISA 22	sherd	15.0	0.0072	0.4800	
ISA 23	sherd	15.0	0.0020	0.1333	
ISA 23a	sherd	15.0	0.0002	0.0133	re-analyzed above without BSTFA
ISA 23b	sherd	15.0	0.0002	0.0133	re-analyzed above with BSTFA
ISA 24	sherd	15.0	0.0104	0.6933	
ISA 25	sherd	15.0	0.0088	0.5867	
ISA 26	chemicals	not msrd	0.0020	n/a	agate mortar/pestle rinse in Teflon
ISA 27	chemicals	not msrd	0.0001	n/a	agate mortar/pestle rinse in glass
ISA 28	sherd	4.4	0.0971	22.2197	
ISA 29	sherd	7.0	0.0075	1.0653	
ISA 30a	sherd	15.1	0.0130	0.8621	top surface of burén
ISA 30b	sherd	12.1	0.0124	1.0273	bottom surface of burén
ISA 31	sherd	9.4	0.0088	0.9342	
ISA 32	sherd	3.5	0.0074	2.1023	
ISA 33	chemicals	not msrd	not msrd	n/a	
ISA 34	chemicals	not msrd	not msrd	n/a	iron mortar/pestle rinse
LEO 01	sherd	15.8	0.0057	0.3617	sonicated whole sherd
LEO 02	sherd	16.0	0.0025	0.1559	same as above but powdered
LEO 03	sherd	15.7	0.0018	0.1143	sonicated whole sherd
LEO 04	sherd	15.4	0.0011	0.0712	same as above but powdered
LEO 05	soil	not msrd	0.0001	n/a	from LEO 01-02
LEO 06	soil	not msrd	0.0011	n/a	from LEO 03-04
LEO 07	soil	12.1	0.0347	2.8797	from site
PER 01	sherd	9.5	0.0165	1.7318	
PER 02	sherd	8.2	0.0132	1.6171	
PER 03	sherd	23.9	0.0079	0.3312	
PER 04	sherd	15.8	0.0934	5.9302	
PER 05	sherd	18.4	0.0182	0.9875	
PER 06	sherd	20.7	0.0062	0.2988	
PER 07	soil	0.6	0.0197	33.3390	from PER 01-06
PM 01	sherd	20.0	0.0142	0.7100	
PM 02	sherd	20.0	0.0171	0.8550	
PM 03	soil	not msrd	0.0248	n/a	from PM 01-02
TAM 01	sherd	9.4	0.0028	0.2985	
TAM 02	sherd	9.4	0.0057	0.6056	
TAM 03	sherd	8.5	0.0068	0.7966	
TAM 04	sherd	8.9	0.0040	0.4485	
TAM 05	sherd	8.7	0.0048	0.5514	
TAM 06	chemicals	not msrd	0.0098	n/a	extracted compounds from wrapping paper
TAM 07	sherd	6.4	0.0018	0.2826	
TAM 08	sherd	4.5	0.0058	1.2972	
TAM 09	sherd	2.4	0.0008	0.3362	
TAM 10	sherd	4.3	0.0071	1.6332	
TAM 11	sherd	10.3	0.0040	0.3873	

ID	*Sample*	*Wt. (g)*	*TLE (mg)*	*R (ug/g)*	*Notes*
TAM 12	sherd	13.6	0.0006	0.0442	
TAM 13	charcoal	1.3	0.0011	0.8680	from TAM 12
TAM 14	sherd	9.6	0.0019	0.1976	
TAM 15	sherd	15.5	0.0024	0.1549	
TAM 16	sherd	6.9	0.0017	0.2452	
TAM 17	sherd	5.3	0.0043	0.8073	
TAM 18a	sherd	14.9	0.0027	0.1815	top surface of burén
TAM 18b	sherd	15.1	0.0030	0.1986	bottom surface of burén
TAM 19a	sherd	15.5	0.0019	0.1225	top surface of burén
TAM 19b	sherd	15.2	0.0011	0.0725	bottom surface of burén
TAM 20	chemicals	not msrd	not msrd	n/a	solvent blank
TAM 21a	sherd	10.7	0.0394	3.6854	steel brushed only
TAM 21b	sherd	10.8	0.0033	0.3049	solvent rinsed only
TAM 22	sherd	9.5	0.0024	0.2529	
TAM 23a	sherd	15.1	0.0510	3.3667	steel brushed only
TAM 23b	sherd	14.0	0.0011	0.0787	solvent rinsed only
TAM 24	sherd	15.1	0.0195	1.2912	
TAM 25a	sherd	15.3	0.0045	0.2941	steel brushed only
TAM 25b	sherd	17.4	0.0043	0.2474	sonicated whole sherd
TAM 25c	sherd	4.5	0.0068	1.5111	solvent rinsed only
TAM 26	sherd	15.4	0.0026	0.1688	
TAM 27	soil	0.1	0.0078	105.9783	from TAM 21-24
TAM 28	soil	0.1	0.0271	333.3333	from TAM 25-26
TAM 29	charcoal	0.1	0.0143	184.5161	from inside TAM 25
TAM 30	chemicals	not msrd	0.0146	n/a	from gloves, hands, hair
X-BSTFA	chemicals	not msrd	not msrd	n/a	derivitizing blank
X-BULB 01	chemicals	not msrd	not msrd	n/a	from bulb direct
X-BULB 02	chemicals	not msrd	not msrd	n/a	from pipette with bulb
X-PUMP	chemicals	not msrd	not msrd	n/a	from pipette with pump

APPENDIX C:

ORGANIC COMPOUNDS IDENTIFIED WITHIN SAMPLES

The following tables present the quantification of compounds as used in this study. The numbers are the percentage of each fatty acid (FA) relative to the total fatty acid content of the sample, each alcohol (OH) relative to the total alcohol content of the sample, and each of the rest of the compounds (named) of interest relative to the total fatty acid and alcohol content of the sample.

	CO 01	***ECZ 02***	***ECZ 05***	***ECZ 11***	***ECZ 13***	***ECZ 15***	***ES 02***
C12:0 FA	0.00	0.00	0.00	100.00	0.00	2.54	0.00
C13:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C14:0 FA	0.00	0.00	5.33	0.00	4.88	24.36	0.00
C15:0 FA	0.00	0.00	1.29	0.00	0.00	3.68	0.00
C16:1 FA	0.00	0.00	70.85	0.00	92.74	35.63	0.00
C16:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C17:1 FA	0.00	0.00	0.73	0.00	0.00	0.00	0.00
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	0.00	0.00	13.09	0.00	2.37	13.05	0.00
C18:1 FA	0.00	0.00	5.73	0.00	0.00	4.99	0.00
C18:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.57	0.00	0.00	0.00	0.00
C20:1 FA	0.00	0.00	2.01	0.00	0.00	0.00	0.00
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.40	0.00	0.00	0.00	0.00
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.00	0.00	0.00	6.46	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C28:0 FA	0.00	0.00	0.00	0.00	0.00	9.29	0.00
C30:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C13	0.00	0.02	0.00	0.00	0.06	0.00	0.08
OH C14	0.00	0.07	0.09	0.29	0.07	0.12	0.00
OH C16	0.00	0.45	0.19	0.65	0.69	0.14	0.00
OH C18	0.00	0.26	0.68	0.00	0.16	0.08	0.45
OH C20	0.00	0.04	0.01	0.00	0.00	0.00	0.00
OH C22	0.00	0.03	0.01	0.00	0.02	0.10	0.00
OH C24	0.00	0.01	0.01	0.06	0.00	0.00	0.47
OH C26	0.00	0.02	0.01	0.00	0.00	0.05	0.00
OH C28	0.00	0.09	0.01	0.00	0.00	0.43	0.00
OH C30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C32	0.00	0.00	0.01	0.00	0.00	0.09	0.00
OH C34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	present	0.00	0.00	0.08	0.02	0.00	0.00
Dehydroabietic acid	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phthalate	present	1.27	0.02	0.10	1.06	10.22	0.01
Squalene	present	0.00	0.00	0.15	0.12	0.00	0.00
Unknown 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAG	0.00	present	0.00	0.00	0.00	0.00	present

	ES 04	*ES 06*	*ES 07*	*ES 09*	*ES 10*	*ISA 01*	*ISA 02*
C12:0 FA	0.00	0.00	1.40	0.00	0.00	0.00	0.00
C13:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C14:0 FA	0.00	0.00	26.51	0.00	11.66	0.00	0.00
C15:0 FA	0.00	0.00	0.00	0.00	2.68	0.00	0.00
C16:1 FA	21.36	0.00	72.09	0.00	44.02	0.00	0.00
C16:0 FA	78.64	0.00	0.00	0.00	9.38	0.00	0.00
C17:1 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	0.00	0.00	0.00	0.00	7.89	0.00	0.00
C18:1 FA	0.00	0.00	0.00	0.00	15.81	0.00	0.00
C18:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20:1 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.00	0.00	7.72	0.00	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.00	0.00	0.00	0.00	0.85	0.00	0.00
C28:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C30:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C32:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C13	0.22	0.16	0.00	0.00	0.00	0.04	0.00
OH C14	0.37	0.42	0.31	0.00	0.03	0.08	0.06
OH C16	0.30	0.26	0.31	0.00	0.28	0.50	0.73
OH C18	0.09	0.15	0.13	0.00	0.09	0.23	0.00
OH C20	0.00	0.00	0.02	0.00	0.07	0.03	0.11
OH C22	0.00	0.00	0.04	0.00	0.08	0.04	0.06
OH C24	0.00	0.00	0.02	0.00	0.10	0.03	0.00
OH C26	0.00	0.00	0.11	0.00	0.03	0.03	0.00
OH C28	0.00	0.00	0.02	0.00	0.11	0.01	0.00
OH C30	0.00	0.00	0.05	0.00	0.17	0.01	0.04
OH C32	0.00	0.00	0.00	0.00	0.04	0.00	0.00
OH C34	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol	0.00	0.00	0.00	present	0.00	0.06	0.19
Dehydroabietic acid	0.00	0.03	0.04	0.00	0.00	1.21	21.98
Phthalate	0.01	0.08	0.01	present	0.00	0.84	27.58
Squalene	0.00	0.00	0.00	present	0.00	0.05	1.58
Unknown 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAG	0.00	present	0.00	0.00	0.00	0.00	present

	ISA 04	*ISA 05*	*ISA 09*	*ISA 10*	*ISA 11*	*ISA 12*	*ISA 15*
C12:0 FA	0.00	0.00	1.93	3.20	0.00	0.00	0.00
C13:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C14:0 FA	0.00	0.00	32.41	24.78	76.02	0.00	0.00
C15:0 FA	0.00	0.00	1.33	3.88	0.00	0.00	0.00
C16:1 FA	0.00	0.00	57.89	48.39	0.00	0.00	20.75
C16:0 FA	0.00	0.00	0.75	7.69	0.00	0.00	0.00
C17:1 FA	0.00	0.00	0.47	0.35	0.00	0.00	8.38
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	0.00	0.00	2.43	11.29	0.00	0.00	70.88
C18:1 FA	0.00	0.00	2.50	0.00	0.00	0.00	0.00
C18:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20:1 FA	0.00	0.00	0.15	0.43	23.98	0.00	0.00
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.00	0.00	0.05	0.00	0.00	0.00	0.00
C28:0 FA	0.00	0.00	0.10	0.00	0.00	0.00	0.00
C30:0 FA	0.00	0.00	0.01	0.00	0.00	0.00	0.00
C32:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C13	0.01	0.00	0.21	0.00	0.02	0.00	0.07
OH C14	0.17	0.30	0.00	0.13	0.12	0.04	0.17
OH C16	0.01	0.37	0.41	0.38	0.23	0.37	0.38
OH C18	0.50	0.20	0.17	0.43	0.59	0.59	0.19
OH C20	0.07	0.00	0.00	0.04	0.03	0.00	0.03
OH C22	0.21	0.00	0.00	0.01	0.00	0.00	0.03
OH C24	0.02	0.00	0.03	0.01	0.01	0.00	0.02
OH C26	0.01	0.00	0.04	0.00	0.00	0.00	0.01
OH C28	0.00	0.06	0.05	0.00	0.00	0.00	0.04
OH C30	0.00	0.00	0.05	0.00	0.01	0.00	0.04
OH C32	0.00	0.00	0.02	0.00	0.00	0.00	0.01
OH C34	0.00	0.07	0.01	0.00	0.00	0.00	0.00
Cholesterol	0.00	0.03	0.00	0.04	0.01	0.00	0.00
Dehydroabietic acid	0.38	5.84	0.89	0.16	0.41	0.00	2.20
Phthalate	11.79	12.39	0.05	4.35	0.25	339.54	59.94
Squalene	0.00	0.04	0.01	0.05	0.01	22.27	0.12
Unknown 1	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Unknown 2	0.00	0.04	0.00	0.00	0.00	0.00	0.00
TAG	0.00	0.00	present	0.00	0.00	0.00	0.00

	ISA 16	*ISA 23*	*ISA 25*	*ISA 31*	*LEO 02*	*LEO 04*	*LEO 07*
C12:0 FA	0.82	0.00	0.00	0.00	0.00	6.72	0.00
C13:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C14:0 FA	5.63	0.00	0.00	8.07	1.63	47.45	0.00
C15:0 FA	1.34	0.00	8.01	7.21	1.54	0.72	0.00
C16:1 FA	58.29	0.00	77.67	46.98	64.77	36.75	0.00
C16:0 FA	0.00	0.00	0.00	14.52	0.81	0.00	0.00
C17:1 FA	0.92	0.00	0.00	0.00	1.31	1.90	0.00
C17:0 FA	0.20	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	25.30	0.00	14.00	3.16	9.28	3.64	0.00
C18:1 FA	7.40	0.00	0.00	20.06	0.00	1.56	0.00
C18:0 FA	0.00	0.00	0.00	0.00	1.84	1.10	0.00
C19:0 FA	0.00	0.00	0.00	0.00	0.34	0.00	0.00
C20:1 FA	0.11	0.00	0.00	0.00	4.12	0.00	0.00
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.00	0.00	1.62	0.00	0.00
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.00	0.00	6.88	0.00	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.00	100.00	0.32	0.00	4.70	0.08	100.00
C28:0 FA	0.00	0.00	0.00	0.00	1.17	0.00	0.00
C30:0 FA	0.00	0.00	0.00	0.00	0.00	0.08	0.00
C32:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C13	0.00	0.00	0.07	0.00	0.00	0.00	0.00
OH C14	0.15	0.30	0.11	0.14	0.04	0.31	0.02
OH C16	0.53	0.29	0.32	0.31	0.05	0.24	0.00
OH C18	0.17	0.08	0.21	0.24	0.06	0.32	0.00
OH C20	0.03	0.03	0.15	0.00	0.01	0.01	0.00
OH C22	0.01	0.05	0.00	0.01	0.03	0.01	0.42
OH C24	0.01	0.14	0.07	0.05	0.05	0.00	0.18
OH C26	0.02	0.07	0.03	0.06	0.06	0.01	0.12
OH C28	0.02	0.04	0.02	0.06	0.07	0.04	0.27
OH C30	0.05	0.00	0.02	0.09	0.53	0.05	0.00
OH C32	0.00	0.01	0.00	0.02	0.09	0.00	0.00
OH C34	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Cholesterol	0.11	0.10	0.01	0.01	0.01	0.00	0.52
Dehydroabietic acid	0.17	0.80	1.67	0.02	0.00	0.00	0.00
Phthalate	3.04	1.02	1.15	0.22	0.07	0.03	11.63
Squalene	0.10	0.01	0.04	0.01	0.01	0.00	2.23
Unknown 1	0.06	0.00	0.00	0.00	0.00	0.00	0.04
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAG	0.00	0.00	0.00	present	present	0.00	present

	PER 02	*PER 03*	*PER 05*	*TAM 02*	*TAM 05*	*TAM 07*	*TAM 08*
C12:0 FA	0.00	0.00	0.00	0.00	36.70	1.40	0.40
C13:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C14:0 FA	93.86	0.00	0.00	0.00	0.00	25.74	11.71
C15:0 FA	0.00	0.00	0.00	0.00	0.00	5.44	1.21
C16:1 FA	0.00	100.00	0.00	21.28	41.23	19.74	83.33
C16:0 FA	0.00	0.00	0.00	0.00	0.00	0.44	0.00
C17:1 FA	0.00	0.00	0.00	1.79	0.00	4.02	1.65
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	5.47	0.00	0.00	23.54	11.53	34.73	1.69
C18:1 FA	0.00	0.00	0.00	4.45	5.19	0.00	0.00
C18:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.00	0.00	0.00	0.88	0.00
C20:1 FA	0.67	0.00	0.00	4.55	0.00	1.88	0.01
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.00	5.46	2.78	2.69	0.00
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.00	22.33	0.00	1.83	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.00	0.00	0.00	6.78	2.57	0.33	0.00
C28:0 FA	0.00	0.00	0.00	3.03	0.00	0.89	0.00
C30:0 FA	0.00	0.00	0.00	6.78	0.00	0.00	0.00
C32:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C13	0.19	0.01	0.00	0.00	0.00	0.00	0.00
OH C14	0.30	0.46	0.00	0.10	0.13	0.17	0.12
OH C16	0.29	0.37	0.00	0.16	0.23	0.38	0.45
OH C18	0.19	0.17	0.00	0.48	0.28	0.25	0.34
OH C20	0.00	0.00	0.00	0.04	0.12	0.04	0.05
OH C22	0.00	0.00	0.00	0.04	0.03	0.04	0.03
OH C24	0.00	0.00	0.00	0.03	0.02	0.03	0.01
OH C26	0.00	0.00	0.00	0.04	0.03	0.03	0.00
OH C28	0.01	0.00	0.00	0.06	0.03	0.03	0.00
OH C30	0.01	0.00	0.00	0.00	0.11	0.02	0.00
OH C32	0.00	0.00	0.00	0.03	0.01	0.01	0.00
OH C34	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Cholesterol	0.37	0.06	present	0.00	0.20	0.01	0.00
Dehydroabietic acid	0.01	0.00	0.00	0.01	0.01	0.00	0.00
Phthalate	11.02	17.59	present	0.26	0.84	0.11	0.68
Squalene	0.13	0.48	present	0.00	0.06	0.00	0.01
Unknown 1	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAG	0.00	present	0.00	present	present	0.00	present

	TAM 09	*TAM 10*	*TAM 11*	*TAM 12*	*TAM 13*	*TAM 14*	*TAM 15*
C12:0 FA	0.00	0.00	0.16	8.99	4.08	0.00	0.00
C13:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C14:0 FA	93.20	0.00	7.99	62.16	43.15	64.03	0.00
C15:0 FA	0.00	0.00	0.29	0.00	2.84	0.00	0.00
C16:1 FA	0.00	0.00	62.56	24.20	25.86	35.97	84.63
C16:0 FA	0.00	0.00	0.00	0.00	10.45	0.00	0.00
C17:1 FA	0.00	0.00	5.09	0.00	1.38	0.00	0.00
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	6.80	0.00	20.85	4.65	4.59	0.00	15.37
C18:1 FA	0.00	0.00	0.56	0.00	2.54	0.00	0.00
C18:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.01	0.00	0.00	0.00	0.00
C20:1 FA	0.00	0.00	1.77	0.00	0.00	0.00	0.00
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.35	0.00	0.68	0.00	0.00
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.21	0.00	3.44	0.00	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.00	0.00	0.05	0.00	0.18	0.00	0.00
C28:0 FA	0.00	0.00	0.06	0.00	0.00	0.00	0.00
C30:0 FA	0.00	0.00	0.04	0.00	0.82	0.00	0.00
C32:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH C13	0.00	0.00	0.00	0.00	0.00	0.06	0.06
OH C14	0.13	0.00	0.11	0.06	0.17	0.14	0.20
OH C16	0.56	0.65	0.40	0.42	0.17	0.29	0.25
OH C18	0.19	0.29	0.34	0.40	0.19	0.28	0.23
OH C20	0.05	0.06	0.05	0.02	0.05	0.02	0.04
OH C22	0.04	0.00	0.04	0.04	0.00	0.03	0.02
OH C24	0.01	0.00	0.02	0.01	0.05	0.02	0.01
OH C26	0.00	0.00	0.02	0.01	0.04	0.04	0.01
OH C28	0.00	0.00	0.01	0.00	0.19	0.04	0.02
OH C30	0.00	0.00	0.00	0.03	0.09	0.05	0.04
OH C32	0.00	0.00	0.00	0.00	0.04	0.02	0.08
OH C34	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Cholesterol	1.49	3.33	0.00	0.45	0.03	0.32	4.98
Dehydroabietic acid	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Phthalate	42.49	4623.22	0.00	1.08	1.53	187.79	400.07
Squalene	1.59	12.69	0.00	0.00	0.05	0.00	0.00
Unknown 1	0.00	19.12	0.00	0.00	0.00	0.05	0.00
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAG	0.00	present	present	present	0.00	present	present

	TAM 16	*TAM 18a*	*TAM 18b*	*TAM 21a*	*TAM 22*	*TAM 23a*	*TAM 24*
C12:0 FA	4.54	7.04	1.36	0.15	1.04	0.00	0.00
C13:0 FA	0.00	0.00	0.00	0.00	0.40	0.00	0.00
C14:0 FA	42.17	24.69	44.51	9.73	26.13	13.91	1.08
C15:0 FA	4.03	5.04	10.10	0.63	2.00	7.06	1.19
C16:1 FA	37.86	37.97	30.28	78.40	39.99	33.16	68.98
C16:0 FA	0.00	5.47	0.00	0.03	0.80	0.00	0.00
C17:1 FA	0.00	5.82	7.50	0.36	4.71	4.48	1.75
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	10.01	1.54	6.25	8.56	14.20	20.08	26.00
C18:1 FA	0.83	7.75	0.00	0.44	1.28	5.56	0.00
C18:0 FA	0.00	3.99	0.00	0.00	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.00	0.31	0.37	0.00	0.24
C20:1 FA	0.00	0.00	0.00	0.61	0.31	1.99	0.22
C20:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:1 FA	0.00	0.00	0.00	0.68	0.00	1.48	0.37
C22:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C24:1 FA	0.00	0.00	0.00	0.09	2.50	8.90	0.00
C24:0 FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C26:0 FA	0.36	0.67	0.00	0.00	1.46	3.38	0.06
C28:0 FA	0.00	0.00	0.00	0.01	2.12	0.00	0.10
C30:0 FA	0.21	0.00	0.00	0.00	0.00	0.00	0.00
C32:0 FA	0.00	0.00	0.00	0.00	2.68	0.00	0.00
OH C13	0.00	0.00	0.00	0.00	0.00	0.03	0.02
OH C14	0.18	0.09	0.19	0.18	0.09	0.09	0.07
OH C16	0.25	0.31	0.33	0.39	0.29	0.25	0.31
OH C18	0.26	0.15	0.38	0.24	0.21	0.18	0.46
OH C20	0.06	0.04	0.03	0.04	0.04	0.08	0.05
OH C22	0.05	0.10	0.04	0.05	0.06	0.09	0.03
OH C24	0.02	0.05	0.02	0.03	0.05	0.07	0.02
OH C26	0.02	0.04	0.01	0.02	0.05	0.08	0.02
OH C28	0.06	0.06	0.01	0.02	0.07	0.05	0.02
OH C30	0.08	0.09	0.00	0.00	0.08	0.04	0.01
OH C32	0.02	0.07	0.00	0.03	0.04	0.03	0.00
OH C34	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Cholesterol	0.00	0.26	0.00	0.00	0.01	0.08	0.00
Dehydroabietic acid	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phthalate	0.80	2.42	9.62	0.27	3.54	4.98	0.27
Squalene	0.01	0.08	0.00	0.00	0.00	0.06	0.00
Unknown 1	0.01	0.27	0.00	0.00	0.00	0.00	0.00
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAG	present	0.00	0.00	0.00	present	present	present

	TAM 25a	*TAM 25b*	*TAM 26*	*TAM 27*	*TAM 29*	*TAM 30*
C12:0 FA	2.22	0.00	0.07	0.00	0.00	0.46
C13:0 FA	0.00	0.00	0.05	0.00	0.00	0.00
C14:0 FA	36.60	34.62	4.96	19.02	12.39	16.53
C15:0 FA	2.90	2.12	4.33	4.86	2.98	0.55
C16:1 FA	27.87	38.27	48.83	44.07	63.88	63.69
C16:0 FA	0.00	0.00	0.74	0.00	0.00	4.63
C17:1 FA	5.20	0.59	5.50	2.41	0.19	1.13
C17:0 FA	0.00	0.00	0.00	0.00	0.00	0.00
C18:2 FA	15.32	9.57	7.28	20.27	11.71	4.05
C18:1 FA	0.54	4.34	11.83	2.46	6.57	8.90
C18:0 FA	0.00	0.00	0.52	0.00	0.00	0.00
C19:0 FA	0.00	0.00	0.27	0.00	0.00	0.00
C20:1 FA	0.00	0.00	0.68	0.23	0.00	0.06
C20:0 FA	0.00	0.00	0.85	0.00	0.00	0.00
C22:1 FA	0.47	1.79	0.38	0.37	0.00	0.00
C22:0 FA	0.00	1.77	1.60	0.00	0.00	0.00
C24:1 FA	6.86	0.00	3.57	0.00	2.28	0.00
C24:0 FA	0.00	0.00	0.77	0.00	0.00	0.00
C26:0 FA	0.00	3.34	1.21	2.46	0.00	0.00
C28:0 FA	0.00	3.59	2.48	3.84	0.00	0.00
C30:0 FA	0.00	0.00	3.31	0.00	0.00	0.00
C32:0 FA	2.03	0.00	0.78	0.00	0.00	0.00
OH C13	0.00	0.00	0.00	0.00	0.00	0.00
OH C14	0.13	0.04	0.06	0.03	0.00	0.02
OH C16	0.34	0.40	0.14	0.15	0.13	0.14
OH C18	0.31	0.11	0.17	0.15	0.10	0.85
OH C20	0.05	0.02	0.11	0.05	0.00	0.00
OH C22	0.05	0.04	0.10	0.10	0.03	0.00
OH C24	0.02	0.05	0.07	0.08	0.00	0.00
OH C26	0.02	0.07	0.12	0.08	0.00	0.00
OH C28	0.02	0.04	0.02	0.11	0.00	0.00
OH C30	0.02	0.05	0.11	0.10	0.74	0.00
OH C32	0.02	0.16	0.06	0.10	0.00	0.00
OH C34	0.00	0.01	0.02	0.03	0.00	0.00
Cholesterol	4.07	0.00	0.01	0.20	0.00	0.00
Dehydroabietic acid	0.00	0.00	0.00	0.00	0.00	0.00
Phthalate	0.52	9.47	0.40	2.91	147.96	0.74
Squalene	0.00	0.18	0.01	0.05	0.00	0.00
Unknown 1	0.00	0.00	0.02	0.00	0.00	0.00
Unknown 2	0.00	0.00	0.00	0.00	0.00	0.00
TAG	0.00	0.00	present	0.00	0.00	0.00

APPENDIX D:

CRITERIA USED FOR RESIDUE IDENTIFICATION

Identification based on degraded residue experiments by Coyston (2002)

Fatty Acid	maize	squash seeds	meat	leafy greens/plant
$C_{12:0}$ –				
$C_{14:0}$ | –	≤1%	5-7%	2-15.5%	5-13%
$C_{15:0}$ –				
$C_{16:1}$	none	≤1.5%	≤2.5%	0-2%
$C_{16:0}$	ca. 10%	none	17-50%	48-57%
$C_{17:1}$	none	0- ca. 1%	none	none
$C_{18:2n6c}$	57%	0-11.5%	11-25%	≤1-8.5%
$C_{18:2n6t}$	ca. 25%	none	15-30%	0-15%
$C_{18:1}$	≤1%	none	≤1-2.5%	0-1%
$C_{18:0}$	ca. 1%	none	12-32.5%	≤1-22.5%
Long chain	6.5%	80-93%	≤1-4%	2.5-38%

$(C_{12:0}+C_{14:0}+C_{15:0})/(C_{20:0}+) < 2$ = plant; ≥ 2 = meat
$C_{20:0}+ \geq 4\%$ = plant; <4 = meat
plants nearly always have larger percentages of the long chain fatty acids; absence = meat
meats are distinguished by higher proportions of $C_{18:2}$ isomers and $C_{18:0}$
freshwater fish = relative abundance of odd-numbered FA
chilies have $C_{18:2}$ isomers comparable to meats, but long chain ca. 7.7%

Identification based on degraded residue experiments by Deal, et al. (1991)

	$C_{18:1}$ ω9 / $C_{18:1}$ ω7
Terrestrial mammal	8.5
Terrestrial plant	5.7
Reptiles	5.2
Sea mammal	3.1
Marine fish	2.0
Mollusk	1.7

$C_{18:1} < 20\%$ = mollusk (but not zero)
$C_{18:0} > 20\%$ = ruminants (modern)
$C_{20:1}$, $C_{24:1}$ = fish
$C_{22:1} > 20\%$ = Cruciferae

Identification based on tentative values calculated by Deal, et al. (1990)

$C_{14:0}$ > 5% = milk and palm seed fats (but also formed by degraded $C_{16:1}$)
$C_{16:1}$ = fish and marine mammals
$C_{18:3}$ = freshwater fish
$C_{18:2}$ = freshwater fish/seed oils
$C_{18:0}$ > 20% = ruminants
$C_{20:1}$ = fish and marine mammals
$C_{24:1}$ = fish and marine mammals

Identification based on material from Dudd, et al. (1999)

$C_{15:0}$ and $C_{17:0}$ branched = ruminants

Identification based on degraded residue experiments by Eerkens (2005)

FA Ratio	terr. mammal	fish	root	green	seed/nut/berry
$(C_{15:0}+C_{17:0})/C_{18:0}$	<0.2	0.2-0.5	>0.2	0.1-1.0	<0.6
$C_{16:1}/C_{18:1}$	0.08-0.8	0.8-2.0	0.2-2.8	>2.8	<1.2
$C_{16:0}/C_{18:0}$	<7.0	8-12	6-24	10-24	0-18
$C_{12:0}/C_{14:0}$	<0.15	<0.15	>0.15	>0.05	>0.15

Identification based on degraded residue experiments by Eerkens (2001)

FA Ratio	terr. mammal	fish	bird	root	green	seed/nut/berry
$\frac{(C_{12:0}+C_{14:0})}{(C_{20:0}+C_{22:0})}$	>3.5	>5	>3	<2	<2	<2
$\frac{(C_{16:0}+C_{16:1})}{(C_{18:0}+C_{18:1})}$	<1	<1.5	>0.5 & <0.8	>1.5	>2	<0.5

Identification based on degraded residue experiments by Malainey, et al. (1999b)

Identification	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$	$C_{18:0}$	$C_{18:1}$ isomers
Large herbivore	≤15%	≥27.5%	≤15%
Herbivore w/plant or marrow	3-8%	≥25%	15% ≤X ≤25%
Plant w/ large herbivore	≥15%	≥25%	No data
Fish/corn	3-8%	≤25%	15% ≤X ≤27.5%
Fish/corn w/plant	≥15%	≤25%	15% ≤X ≤27.5%
Plant (except corn)	≥10%	≤27.5%	≤15%

Identification based on degraded residue experiments by Marchbanks (1985)

	$(C_{12:0}+C_{14:0})/(C_{18:2}+C_{18:1})$ x 100
Plant	0-18
Fish	25-40
Land animal	48-100

Criteria for degraded residue identification based on experiments by Reber (2001)

OH C_{32} = maize
$(C_{15:0}+C_{17:0})/(C_{12:0}+C_{14:0}+C_{16:0}+C_{18:0}) > 0.04$ = ruminant animals
$C_{16:0}/C_{18:0} > 1.0$ (and high degree unsaturated FA) = plant/fish presence
Long chain alcohols = plant

APPENDIX E:

CURRICULUM VITA

JAMES MICHAEL VANDERVEEN

Department of Anthropology • Indiana University • Bloomington, Indiana 47405

office Student Building 130
telephone (812) 855-1041
e-mail jmvander@indiana.edu

EDUCATION

2006 Ph.D., Archaeology and Social Context
Department of Anthropology, Indiana University, Bloomington
Doctoral Dissertation: "Subsistence Patterns as Markers of Cultural Exchange: European and Taíno Interactions in the Dominican Republic" (Simon C. Brassell, Geoffrey W. Conrad, K. Anne Pyburn, Richard R. Wilk)

2005 M.A., Historical Anthropology
Department of Anthropology, Indiana University, Bloomington
Thesis: "History of a Pioneer House: Domestic Archaeology in Context." (Geoffrey W. Conrad, Paul R. Mullins, April K. Sievert)

1996 B.A., Anthropology; Concentration in Public Policy
Department of Anthropology and Sociology, Albion College, Albion, Mich.
S*umma cum laude,* with departmental honors
Honors Thesis: "An Intrasite Analysis of Political and Economic Wealth as Determined by Ceramic Assemblages Excavated in Postclassic Xaltocan, Mexico" (Elizabeth M. Brumfiel, Frank S. Frick)

SPECIALIZATIONS

Prehistoric and Historic Caribbean (including eastern Mesoamerica), contact between cultures, patterns of foodways and subsistence, political and economic access
Marine research, scientific diving, underwater park development
Social context of research, public outreach of archaeology, cultural property rights
Historic North America (Midwest), class and race issues

PROFESSIONAL MEMBERSHIP

Indiana Academy of Science
International Association for Caribbean Archaeology
Sigma Xi – National Scientific Research Society
Society for American Archaeology
  Public Archaeology Interest Group
  Rock Art Interest Group
Society for Archaeological Sciences
Phi Beta Kappa – National Scholastic Honorary Society

AWARDS, GRANTS, AND HONORS

2005-2006	*J. Stewart and Dagmar K. Riley Graduate Fellowship* ($15,000) College of Arts and Sciences, Indiana U.
2004, 2005	*Doctoral Student Grant-in-Aid of Research Award* ($600, $745) The University Graduate School, Indiana U.
2005	*Research Award* ($485) Graduate and Professional Student Organization, Indiana U.
2005	*Harold K. Schneider Economic Anthropology Paper Prize* ($200) Department of Anthropology, Indiana U.
2005	*Professional Conference Paper Award* ($200) College of Arts and Sciences, Indiana U.
2004	*Departmental Summer Fieldwork Support Award* ($3,000) David C. Skomp Fellowship, Dept. of Anthropology, Indiana U.
2004	*Grant-in-Aid of Research Award* ($753, award number 3040301) Sigma Xi, The Scientific Research Society
2004	*Mendel Pre-dissertation Grant* ($600) Center for Latin American and Caribbean Studies, Indiana U.
2004	*Outstanding Graduate Instructor Teaching Award* ($500) Department of Anthropology, Indiana U.
2003-2004	*Future Faculty Teaching Fellowship* ($16,000) Research and the University Graduate School, Indiana U.
2000, 2002-2005	*Paper Presentation Award* ($200 each instance) David C. Skomp Fellowship, Dept. of Anthropology, Indiana U.
2002, 2003	*Tinker Foundation Field Research Grant* ($1,000 each instance) Center for Latin American and Caribbean Studies, Indiana U.
2002	*Outstanding Associate Instructor Teaching Award* ($500) Department of Anthropology, Indiana U.
2002	*President's Summer Undergraduate Research Initiative* ($4,500) Research and the University Graduate School, Indiana U.
1997	*Graduate Research Fellowship Honorable Mention* National Science Foundation
1996	*Notestein Award for Outstanding Scholarship in Anthropology* Anthropology and Sociology Department, Albion College
1996	*Omicron Delta Kappa* National Leadership Honorary Society

AWARDS, GRANTS, AND HONORS (CONTINUED)

1995	*Finalist* Harry S Truman Foundation Public Policy Scholarship
1994	*President's Fellow* Albion College
1994	*Pi Sigma Sigma* Public Policy Honor Society
1993-1996	*Gerald R. Ford Institute for Public Service Scholarship* Albion College
1993	*Alpha Lambda Delta* National Freshman Honor Society
1992-1996	*Trustees' Scholarship* Albion College
1992	*Merit Scholar* National Merit Scholarship Program

ACADEMIC POSITIONS

Fall '06-present	Assistant Professor, Dept. of Sociology and Anthropology, IUSB
Fall '04-Spring '05	Associate Faculty, Department of Anthropology, IUPUI A103: Human Origins and Prehistory (2 sections/semester)
Fall '03-Spring '04	Visiting Assistant Professor, Department of Anthropology, IUPUI A103: Human Origins and Prehistory (1 section/semester) E335: Ancient Civilizations of Mesoamerica P220: Rise of Ancient Civilizations
Fall '02-Spring '03	Graduate Instructor, Department of Anthropology, Indiana U. B301: Laboratory in Bioanthropology
Fall 2002	Graduate Instructor, Collins Living-Learning Center, Indiana U. L225: Pastimes of Times Past
Summer 2002	Graduate Instructor, Department of Anthropology, Indiana U. A105: Human Origins and Prehistory A303: Evolution and Prehistory
Fall '01-Spring '02	Associate Instructor, College of Arts and Sciences, Indiana U. E104: Rise and Fall of Ancient Civilizations (G.W. Conrad) E104: Lost Tribes and Sunken Continents (K.A. Pyburn)
Summer 2001, 2002	Instructor, Social Science Division, Martin University Next Step Education through Archaeology Project
Fall '00-Spring '01	Associate Instructor, College of Arts and Sciences, Indiana U. E104: Rise and Fall of Ancient Civilizations (G.W. Conrad) E105: Darwinian Medicine (P. Jamison)
Fall '99-Spring '00	Laboratory Instructor, Kelley School of Business, Indiana U. X220: Introduction to Career Perspectives

RESEARCH EXPERIENCE

August 2004-present	*Research Associate* Indiana U. Biogeochemical Laboratory (S. Brassell, supervisor)
July-August 2005	*Field Crew Chief and Laboratory Director* Indiana U. Bahía Isabela Archaeological Project El Castillo, Dominican Republic (G. Conrad, supervisor)
November 2004	*Field Crew Chief* Indiana U. Bahía Isabela Archaeological Project El Castillo, Dominican Republic (G. Conrad, supervisor)
July 2004	*Field Crew Chief* Indiana U. Bahía Isabela Archaeological Project El Castillo, Dominican Republic (G. Conrad, supervisor)
June-July 2003	*Field Crew Chief* Indiana U. Dive into History Project Bayahibe, Dominican Republic (G. Conrad, supervisor)
March 2003	*Field Crew Chief* Guaraguao Reef Cannons Preserve Bayahibe, Dominican Republic (C. Beeker, supervisor)
July-August 2002	*Field Crew Chief and Laboratory Director* Indiana U. La Cangrejera Oeste Project Bayahibe, Dominican Republic (G. Conrad, supervisor)
March 2002	*Field Crew Chief* 1724 Guadalupe Underwater Archaeological Preserve Bayahibe, Dominican Republic (C. Beeker, supervisor)
February 2002	*Field Crew Member* Earth Watch Paradise Park Project Westmoreland, Jamaica (W. Keegan, supervisor)
June-August 2001	*Research Director* Martin U. Next Step Education through Archaeology Project Indianapolis, Indiana (H. Murphy, supervisor)
June-August 2000	*Laboratory Director* Martin U. Next Step Education through Archaeology Project Indianapolis, Indiana (H. Murphy, supervisor)
May-June 2000	*Field Crew Member* Glenn Black Laboratory in Archaeology/Indiana U. Field School Shoals, Indiana (S. Ball, supervisor)
March 2000	*Field Crew Member* Indiana U. Dive into History Project Bayahibe, Dominican Republic (C. Beeker, supervisor)
January-May 1996	*Archaeological Technician* Cultural Commonwealth Resources Group Jackson, Michigan (D. Weir, president)

PUBLISHED WORKS

2005 El Reconocimiento Arqueológico de la Regíon de Bahía Isabela. *Boletín del Museo del Hombre Dominicano* 39: 43-47.

2004 Site Preservation or Self Preservation?: The Issue of Stewardship and Control. *The SAA Archaeological Record* 4(1): 30-33.

2003 Review of *Archaeology at La Isabela: America's First European Town*, by Kathleen Deagan and José María Cruxent; and *Columbus's Outpost among the Taíno: Spain and America at La Isabela, 1493—1498*, by Kathleen Deagan and José María Cruxent. *Latin American Antiquity* 14: 504-506.

2000 An Analysis of the Historic Ceramic Assemblage from Site 12Ma648 (co-authored with Edwin Huggins). In *2000 Addendum to the 1999 Archaeological Investigations of Site 12Ma648 at Fort Benjamin Harrison State Park, Marion County, Indiana*, edited by John P. Hale, pp. C72-C85. Submitted to the Indiana Division of Historic Preservation and Archaeology. Copies available from the Office of the State Historic Preservation Officer, Indianapolis, Indiana.

1998 Power on a Platter: Household Political and Economic Wealth in Postclassic Xaltocan, Mexico. *Chicago Anthropology Exchange* 27: 25-53.

1995 *The Albion Journal of Contemporary Affairs,* volume 5 (editor). Gerald R. Ford Institute of Public Service, Albion, Michigan.

PAPERS IN PRESS

in press A New Look at Old Food: Reconstructing Subsistence Patterns at La Isabela, Dominican Republic. *Proceedings of the XXI International Congress for Caribbean Archaeology,* edited by Basil Reed. University of the West Indies, St. Augustine, Trinidad and Tobago.

in press Compositional Analysis of Ceramic Artifacts from La Aleta, Dominican Republic. (Co-authored with Geoffrey W. Conrad, Christophe Descantes, and Michael Glascock.) *Proceedings of the XXI International Congress for Caribbean Archaeology,* edited by Basil Reed. University of the West Indies, St. Augustine, Trinidad and Tobago.

in review People, Pots, and Prosperity: The Ceramic Value Index and an Assumption of Economic Class. *Midcontinental Journal of Archaeology.*

in review Reconstructing the Geometric and Morphological Performance Characteristics of Ancient Water Storage Bottles from the Dominican Republic. *Caribbean Journal of Science.*

GOVERNMENTAL REPORTS

2005 *Registro de Unidades y Muestras Recogidas del Tamarindo*. Submitted to El Museo del Hombre Dominicano. Copies available from El Museo del Hombre Dominicano, Santo Domingo, Dominican Republic.

2005 *Suggested Site Numbering System for the Dominican Republic.* (Co-authored with Geoffrey W. Conrad and Charles D. Beeker.) Submitted to El Museo del Hombre Dominicano. Copies available from El Museo del Hombre Dominicano, Santo Domingo, Dominican Republic.

2004 *El Reconocimiento Arqueológico de la Regíon de Bahía Isabela*. (Co-authored with Geoffrey W. Conrad). Submitted to El Museo del Hombre Dominicano. Copies available from El Museo del Hombre Dominicano, Santo Domingo, Dominican Republic.

2002 *La Examinación Arqueológica en La Rosa de Bayahibe.* (Co-authored with Geoffrey W. Conrad.) Submitted to El Museo del Hombre Dominicano. Copies available from El Museo del Hombre Dominicano, Santo Domingo, Dominican Republic.

2001 *Archaeological Investigation of Site 12Ma648 at Fort Harrison State Park, Marion County, Indiana*. Submitted to the Indiana Division of Historic Preservation and Archaeology. Copies available from the Office of the State Historic Preservation Officer, Indianapolis, Indiana.

PROFESSIONAL CONFERENCE PRESENTATIONS

2006 "Archaeology of the Accessible: How Political and Economic Development Shape Caribbean Research." 71st Annual Society for American Archaeology Meeting. San Juan, Puerto Rico. April 26-30.

2005 "Form, Function, and Fresh Water: Reconstructing the Use of Storage Bottles in Ancient Limestone Environments." Indiana Academy of Science 121st Annual Meeting. Saint Mary-of-the-Woods College, Saint Mary-of-the-Woods, Indiana. October 5-6.

2005 "A New Look at Old Food: Reconstructing Subsistence Patterns at La Isabela, Dominican Republic." XXI International Congress for Caribbean Archaeology. University of the West Indies, St. Augustine, Trinidad and Tobago. July 24-30.

2005 "Compositional Analysis of Ceramic Artifacts from La Aleta, Dominican Republic." Co-authored with Geoffrey W. Conrad, Christophe Descantes, and Michael Glascock. XXI International Congress for Caribbean Archaeology. University of the West Indies, St. Augustine, Trinidad and Tobago. July 24-30.

PROFESSIONAL CONFERENCE PRESENTATIONS (CONTINUED)

2004	"Substantiating Subsistence: Patterns of Food Production as Identified through Residue Analysis in Ceramics." Indiana Academy of Science 120th Annual Meeting. Hanover College, Hanover, Indiana. October 28-29.
2004	"Sometimes a Cigar is Just a Cigar: A Reevaluation of Taíno Symbolic Analysis." 69th Annual Society for American Archaeology Meeting. Montreal, Quebec. March 31 – April 4.
2003	"Digging for Dollars: The Impact of National Wealth on Anthropology." Central States Anthropological Society Annual Meeting. Louisville, Kentucky. April 17-20.
2003	"The Competing Interests of Private Gain and Public Good." 68th Annual Society for American Archaeology Meeting. Milwaukee, Wisconsin. April 9-13.
2002	"The Problem of Paradigms and Prehistory: How Politics and Prosperity Help Construct the Past." Midwest Archaeology Conference. Columbus, Ohio. October 3-6.
2002	"Ceramics and the Divisions of Economic Class." Paul Lucas Conference in History. Indiana University, Bloomington, Indiana. April 6.
2001	"An Early Start in the Past." Panel on Public Anthropology Today. Indiana University, Bloomington, Indiana. January 25.
2000	"Same Pots, Dissimilar Places?: A Comparison of Frontier Indiana Ceramic Assemblages." Joint Midwest Archaeology/Plains Anthropology Conference. St. Paul, Minnesota. November 9-12.
2000	"An Analysis of the Historic Ceramic Assemblage from Site 12Ma648." (Co-authored with Edwin Huggins.) Joint Midwest Archaeology/Plains Anthropology Conference. St. Paul, Minnesota. November 9-12.

INVITED LECTURES

2005	"You Are What You Eat: How Science Uses Food to Tell About Culture." Anthropology Department Brown Bag Lunch. Indiana University-Purdue University, Indianapolis, Indiana. September 28.
2005	"Results of the Bahía Isabela Archaeological Reconnaissance Project." Mendel Research Symposium. Indiana University, Bloomington, Indiana. April 15.
2005	"Penis Pots and Venus Dolls: The Misinterpretation of Prehistoric Sex." Anthropology Department Brown Bag Lunch. Indiana University-Purdue University, Indianapolis, Indiana. January 27.

INVITED LECTURES (CONTINUED)

2004 "The Role of Civility in Ancient Civilizations." Introductory Archaeology Course taught by Katherine Glidden. Indiana University-Purdue University, Indianapolis, Indiana. December 11.

2004 "Modern Power Plays on the Ball Courts of the Past." Anthropology Department Brown Bag Lunch. Indiana University-Purdue University, Indianapolis, Indiana. January 29.

2003 "Archaeological Conflicts Above and Below Ground: Preliminary Excavations at Bayahibe, Dominican Republic." Tinker Research Symposium. Indiana University, Bloomington, Indiana. February 14.

2002 "The Social Context of Ancient Sports, or The Games People Still Play." Four Sub-Field Dialogue on Cultures of the Americas. Indiana University, Bloomington, Indiana. November 14.

2001 "The Research Significance of Fort Harrison." Next Step Archaeology Project Research Symposium. Martin University, Indianapolis, Indiana. August 3.

2000 "Notes from the Laboratory." Next Step Archaeology Project Research Symposium. Martin University, Indianapolis, Indiana. August 4.

SYMPOSIA AND COLLOQUIA ORGANIZED OR CHAIRED

2005 "Indiana Anthropology," with Evelyn Bowers. Indiana Academy of Science 121st Annual Meeting. Saint Mary-of-the-Woods College, Saint Mary-of-the-Woods, Indiana. October 5-6.

2003 "Constructing a New Archaeological Context: The Influence of Stakeholders on the Study of the Past," with Sarah Wille, and sponsored by the SAA Ethics Committee. 68th Annual Society for American Archaeology Meeting. Milwaukee, Wisconsin. April 9-13.

2001 "Public Anthropology Today." Indiana University, Bloomington, Indiana. January 25.

WORKSHOP PARTICIPANT

2003 Future Faculty Teaching Fellows Summer Institute, Bloomington, Indiana, July 17-20.

2002 Making Archaeology Teaching Relevant in the XXIst Century, Bloomington, Indiana, September 5-7.

PROFESSIONAL SERVICE

2006	*Chair* Anthropology Section, Indiana Academy of Science
2005	*Artifact Accession Policy Sub-Committee* Museo del Hombre Dominicano
2005	*Vice-Chair* Anthropology Section, Indiana Academy of Science
2003-2005	*Curriculum Committee* Department of Anthropology, IUPUI
2001-2002	*Policy Committee* William Hammond Mathers Museum of World Culture, Indiana Univ.
2000-2002	*Curriculum Committee* Department of Anthropology, Indiana University
2000-2001	*President* Anthropology Graduate Student Association, Indiana University
1999-2000	*Vice President* Anthropology Graduate Student Association, Indiana University
1995-1996	*Editor-in-Chief* Journal of Contemporary Affairs, Albion College

PUBLIC OUTREACH

2005-2006	Exhibitor, "L'actualité de la Recherche" Musée Départemental d'Archéologie Précolombienne et de Préhistoire. Fort de France, Martinique.
2005	Youth Educator, "Latin American Culture and Stories" Young Learners Section, Morgan County Public Library. Martinsville, Indiana.
2003	Exhibit Construction and Tours, "Dive into History" Guaraguao Reef Cannons Preserve. Bayahibe, Dominican Republic.
2002	Exhibit Construction and Tours, "Dive into History" 1724 Guadalupe Underwater Archaeological Preserve. Bayahibe, Dominican Republic.
1999-2002	Exhibitor, "Archaeology Day" Department of Natural Resources/William Hammond Mathers Museum of World Cultures. Bloomington, Indiana.
2001, 2002	Youth Educator, "Bone Bag" Indianapolis Public Schools. Indianapolis, Indiana.
2001, 2002	Tour Guide, "History and Archaeology in your Backyard" Fort Harrison State Park. Indianapolis, Indiana.