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The Proof Is in the Pots: Residue Analysis of Virgin Branch Puebloan Ceramics

Brenna Lynn Wilkerson
University of Nevada, Las Vegas

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THE PROOF IS IN THE POTS: RESIDUE ANALYSIS OF VIRGIN BRANCH PUEBLOAN
CERAMICS

By

Brenna Lynn Wilkerson

Bachelor of Arts – Anthropology
Auburn University
2013

Bachelor of Arts – French
Auburn University
2013

A thesis submitted in partial fulfillment
of the requirements for the

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College of Liberal Arts
The Graduate College

University of Nevada, Las Vegas
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Brenna Lynn Wilkerson

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Master of Arts – Anthropology
Department of Anthropology

Karen G. Harry, Ph.D.
Examination Committee Chair

Kathryn Hausbeck Korgan, Ph.D.
Graduate College Interim Dean

Liam Frink, Ph.D.
Examination Committee Member

Barbara Roth, Ph.D.
Examination Committee Member

Vernon Hodge, Ph.D.
Graduate College Faculty Representative

Abstract

This study focuses on better understanding diet and subsistence strategies among Virgin Branch Puebloan groups living in the Moapa Valley in southern Nevada and on the Shivwits Plateau in northwestern Arizona. Gas chromatography-mass spectrometry (GC-MS) was used to identify absorbed food residues in three types of Virgin Branch Puebloan ceramics (Moapa Gray Ware, Shivwits Ware, and Tusayan Virgin Series). The data produced by the residue analysis were used to compare patterns of subsistence between Virgin Branch Puebloan sites in the lowlands along the Muddy River and at upland sites on the Shivwits Plateau as these two areas have different environments and available resources. The results suggest little difference in the types of foods found in ceramics from each area and that people in both areas were cooking primarily seeds, nuts, and roots *or* large herbivores. Additionally, I compared the residues found in the three ceramic wares to see if they were used to prepare different types of foods. No difference was found in the types of residues present in the three wares.

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Chapter 1: Introduction and Background

Food is one of the most fundamental aspects of human life, and all human societies make decisions about what foods to eat, how to procure foods, and how to prepare them. The decisions that people make regarding what foods to eat (i.e. diet) and how to procure these foods (i.e. subsistence strategies) can affect more than individual health and nutrition; they can also shape how people interact with others (e.g. through exchange relationships and food distribution networks), as well as with the surrounding environment and landscape.

Diet, subsistence strategies, and the role of food in human societies have long been important topics in archaeological research. Studies include those aimed at the origins of agriculture and food provisioning in complex societies. In the North American Southwest, the introduction of maize agriculture and its effects on prehistoric groups living in this area have been popular subjects of research. Much of this work focuses on determining when maize agriculture first arrived in the Southwest and how it arrived (i.e. diffusion versus migration) (see Huckell 1990 and Whittlesey and Ciolek-Torello 1996).

However, relatively little work looking at diet and subsistence strategies has been done among Virgin Branch Puebloan (VBP) groups who occupied parts of northern Arizona, southern Nevada, and southern Utah. In particular, little archaeological research has been done on VBP groups living on the Shivwits Plateau (located on the north rim of the Grand Canyon) compared to the lowlands of the Moapa Valley. This study focuses on better understanding VBP diet and subsistence strategies in the Moapa Valley and on the Shivwits Plateau through the use of residue analysis to identify subsistence residues left on VBP ceramics.

While archaeologists have long been interested in studying food among prehistoric populations, the first studies focusing on identifying organic residues did not occur until the 1970s. Today, the field of residue analysis in archaeology has taken off thanks to new chromatographic methods developed in the 1950s and 1960s (Oudemans and Boon 1991; Evershed 2008). Specifically, Evershed (2008:896) writes that the combination of gas chromatography and mass spectrometry made detailed studies on organic residues possible. Archaeologists use a variety of analytical techniques to examine microscopic residues found at archaeological sites such as gas chromatography and mass spectrometry (GC-MS), liquid chromatography and mass spectrometry (LC-MS), gas chromatography with a flame ionization detector (GC), and gas chromatography-combustion-isotope ratio analysis (GC-C-IRMS). While most studies look at organic residues remaining in ceramics, studies have expanded to look at residues left on fire-cracked rocks, stone tools, and floors (see Middleton et al. 2010). This study uses gas chromatography and mass spectrometry to identify organic residues left in Virgin Branch Puebloan ceramics in order to better understand overall VBP diet and subsistence strategies, as well as differences in these patterns between upland and lowland groups.

In Chapter 2, I discuss my research design. In Chapter 3, I review my methods and types of residue analysis commonly used in archaeological research. Chapter 4 includes the results of my residue analysis, and Chapter 5 contains my concluding remarks.

Previous Research

Compared to other areas of the Southwest, the Virgin Branch Puebloan culture is one of the least studied groups: “The Virgin Anasazi region is the least known of the six Anasazi subdivisions” (Lyneis 1992). Some of the first excavations in the Moapa Valley were conducted

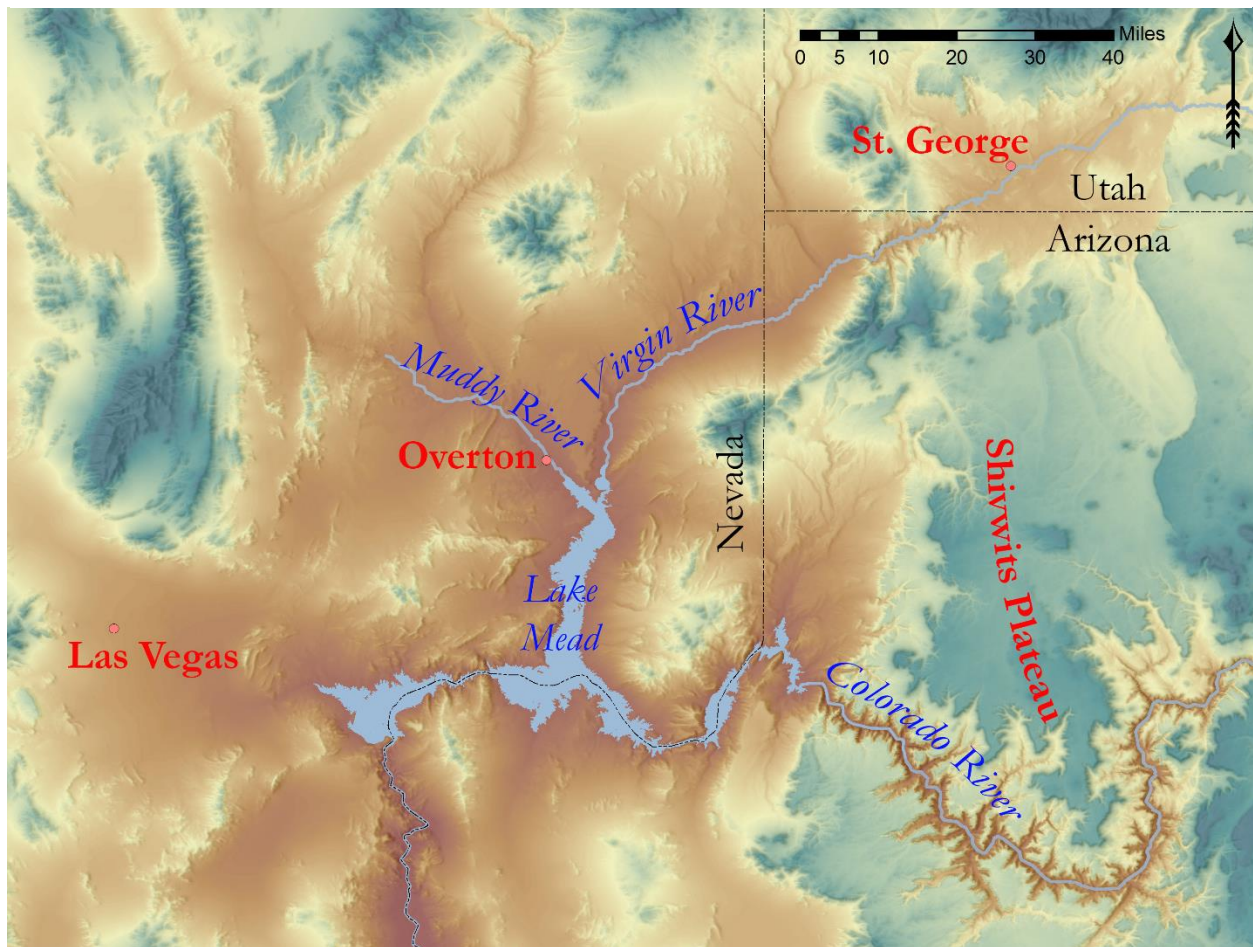
at the Main Ridge community in the 1920s under the direction of Colonel James G. Scrugham, and later Mark R. Harrington, but the first monograph on Main Ridge was not published until 1961 by Richard Shutler (Harry and Watson 2010; Lyneis 1992). Since that time, archaeologists at the University of Nevada, Las Vegas (UNLV) have expanded upon Harrington's work and conducted further excavations at Main Ridge in 2006 with the goal of researching subsistence strategies used in this area (Harry and Watson 2010).

Compared to the lowland Virgin area, the Shivwits Plateau is even less represented in archaeological research. Dr. Karen Harry (2014:1) writes that this area is "one of the most poorly understood areas in Southwestern archaeology." Archaeological research in this area began in 1942 with Baldwin's survey of the Shivwits Plateau, Grand Wash Cliffs, Wolfhole-Poverty Mountain, and Whitmore Wash (Wells 1991). Between 1950 and 1982, five other surveys were conducted; however, the first excavations were not performed until 2006 when Brigham Young University and the University of Nevada, Las Vegas (UNLV) held separate field schools on the Shivwits Plateau. Currently, UNLV and the Lake Mead National Recreation Area, National Park Service (LAKE) have partnered together to create the Shivwits Research Project (SRP) dedicated to researching prehistoric archaeology on the Shivwits Plateau. This project, directed by Dr. Karen Harry, focuses on providing more information about Virgin Branch Puebloan subsistence activities, diet, settlement patterns, exchange networks, and abandonment (Harry 2014).

Location and Environmental Context

The Virgin Branch Puebloan (VBP) people are considered the western-most branch of the Ancestral Puebloan cultures. From approximately 300 B.C. to A.D. 1200, they occupied parts of modern-day southern Nevada, southwestern Utah, and northwestern Arizona. The Colorado

Figure 1.1: Map showing location of Muddy River and Shivwits Plateau



River marks the southern border of the VBP area, and the area beyond the river was inhabited in the historic period by Yuman-speaking peoples. Fremont groups occupied the area north of the St. George Basin, including parts of the northern Colorado Plateau and eastern Great Basin. Kayenta Anasazi groups inhabited the area to the east, but the border between these two regions is fuzzy and debated. Lyneis (1995:201) proposes that the border lies slightly east of Kanab Creek, but VBP sites have been identified east of Kanab Creek at nearby Johnson Creek, such as the Dead Raven Site (Walling and Thompson 2004). Determining the eastern extent of the VBP region is further complicated by the migration of Kayenta groups, as archaeologists believe that

the Kayenta expanded into parts of the Virgin Branch Puebloan area around A.D. 1050 (Lyneis 1995:201).

The Virgin Branch Puebloan area can be divided into three geographic and ecological zones (or districts as in Lyneis 1996): (1) the plateaus, (2) the St. George Basin, and (3) the lowlands. The St. George Basin and the lowlands are located in the Basin and Range physiographic province, and the plateaus form part of the Colorado Plateaus physiographic province. Each of these areas has significantly different environments and climates which affect the type of wild plant and animal resources available, as well as the conditions for agriculture. In general, elevation and the average annual precipitation decrease from east to west (Lyneis 1995). As this would affect the diet and subsistence strategies feasible in these areas, a description of each district follows.

The Plateaus

The plateaus, often referred to as the uplands, are located in the Grand Staircase region. This area is comprised of a series of north-south trending plateaus, forming the western portion of the Colorado Plateaus (Lyneis 1995). Margaret Lyneis (1996) further divides this area into two districts, the Western Plateaus and the Eastern Plateaus, based on their location relative to Kanab Creek. This study focuses on the Western Plateaus, as the upland Virgin Branch Puebloan sites included in this study are located on the Shivwits Plateau to the west of Kanab Creek. Furthermore, it is hypothesized that two of the ceramic wares examined in this study (Shivwits Plain Ware and Moapa Gray Ware) were produced in the Western Plateaus; the proposed origin being the southern portion of the Shivwits Plateau for the former and the area near Mt. Trumbull (to the northwest) for the latter (Harry et al. 2013, Lyneis 2008).

The Shivwits Plateau is located inside the Grand Canyon-Parashant National Monument in northwestern Arizona and is bordered to the south by the Grand Canyon. It is the westernmost plateau on the Arizona Strip and measures approximately 75 miles long from north to south and 25 miles wide from east to west. The elevation on the plateau is an average of 6,000 feet above sea level (asl), but the peak of Mt. Dellenbaugh in the northern portion of the plateau reaches 7,000 feet asl. The precipitation in this area follows a bimodal pattern with rains falling in both the summer and winter; however, a majority of the precipitation (about 60 percent) occurs in winter (Lyneis 1995). On average, the Shivwits Plateau receives approximately 10 to 15 inches (23-33 cm) of precipitation annually, enough to support dry farming in some cases. There are no nearby permanent water sources and few springs on the Shivwits Plateau (Harry 2014), so habitation sites are not found along creeks and rivers. Habitation structures have been found along Kanab Creek and Johnson Creek to the east, but the level of precipitation in the uplands allows for sites to be located in a wider variety of environmental settings (Lyneis 1995:210).

The vegetation in this area varies according to elevation and includes pinyon-juniper woodlands (which typically grow at higher elevations), ponderosa pines (*Pinus ponderosa*), and sagebrush (*Artemesia* sp.). Other wild plant resources found at sites on the plateaus include agave (*Agave* sp.), yucca (*Yucca* sp.), sunflower seeds (*Helianthus*) buckwheat (*Eriogonum* sp.), globemallow (*Sphaeralcea* sp), and groundcherry (*Physalis* sp.). Several varieties of cacti are also present on the Shivwits Plateau including prickly pear (*Opuntia* sp.), and cholla (*Cylindropuntia* sp.). Large mammals found in the uplands include mule deer (*Odocoileus hemionus*). Additionally, small mammals such as jackrabbits (*Lepus* sp.) and cottontails (*Silvilagus* sp.) are extremely common at uplands sites (Wells 1991; Lyneis 1995).

The St. George Basin

The St. George Basin is located in southwestern Utah (near the modern town of St. George) and northwest of the Shivwits Plateau. The elevation in this district is significantly lower than that of the nearby plateaus but higher than the area surrounding the Muddy River; sites are generally located an elevation 800 to 1300 m above sea level (asl). The growing season in the St. George Basin is over 200 days, an incredibly long amount of time compared to the plateaus. On average, this area receives about 21 cm (approximately 8 in) of precipitation annually with most of the rainfall occurring in the winter. Although this is not enough rainfall to allow for dry farming, the St. George Basin lies at the intersection of the Santa Clara River, Leeds Creek-Quail Creek, and the Virgin River (with the former two joining the latter) which could have been irrigation. Additionally, there are several springs and drainages present throughout the basin which are characterized by riparian plant species. In this area, habitation sites are often located in elevated areas near creeks and rivers near agricultural land (Lyneis 1995:210). The lowland areas in the Basin are characterized by Mohave Desertscrub, including creosote (*Larrea tridentata*), although nearby uplands (which are within 16 km) support Pondersosa pine forests, Great Basin Conifer Woodlands, Interior Chaparral, and Great Basin Desertscrub. As in the uplands, the animals available in the St. George Basin include mule deer, bighorn sheep, jackrabbits, and cottontails (Watson 2008; Lyneis 1995).

The Lowlands

The lowland area lies in the Basin and Range physiographic province and includes both the Virgin River Drainage and the Muddy River Drainage. The elevation in this area ranges from 250 to 500 m (roughly 1,150 to 1,640 ft asl). It has a long growing season at 180 days and

receives an average of 10 cm of precipitation per year, with only about one-third of the rain falling in summer months. This level of rainfall is not enough to support dry farming, but, unlike the plateaus, this area contains two major sources of water which could be used for irrigation: the Virgin River and the Muddy River. Many habitation sites are located near the Muddy River and Virgin River and close to agricultural lands (Lyneis 1995:210), with a higher site density located along the Moapa River than the Virgin River during the Pueblo I to early Pueblo III period (Lyneis 1996:14). The two rivers have different origins and streamflows which could affect the potential for agriculture and type of agricultural methods used along their banks, so a brief description of the two rivers follows.

The Virgin River originates from snowmelts in the southern portion of the Great Basin, near southern Utah, and flows southwest toward the St. George Basin. Today, thanks to the Hoover Dam, the Virgin River joins Lake Mead. The volume of the Virgin River is inconsistent: “Streamflow volumes fluctuate greatly from year to year, and flows have been known to cease altogether” (Larson and Michaelsen 1990:229). The Muddy River, conversely, is more consistent. It is a spring-fed tributary of the Virgin River, originating in the Coyote Springs Valley to the west and flowing approximately 46 km through the Moapa Valley before joining the Virgin River in southern Nevada (Lyneis 1995; Larson and Michaelsen 1990). Larson (1996) notes that the conditions of the Muddy River today are dramatically different from conditions during the prehistoric period due to the invasion of exotic species (such as tamarisk) and high levels of irrigation. He writes that the “Muddy River probably meandered over a very large area of pristine bottomland of the Upper and Lower Moapa Valley, and that the valley’s wild resources, agricultural lands, and game were more abundant than they are today” (Larson 1996:67).

The wild plant resources in this area vary based on elevations. The valley floors are characterized by Mohave Desert scrub: creosote (*Larrea tridentata*), cholla (*Cylindropuntia* sp.), beavertail cactus (*Opuntia basilaris*), bursage (*Ambrosia dumosa*). Mesquite, which is generally found at lower elevations, is an important plant resource available in the lowlands which does not occur in the uplands (Lyneis 1995; Allison 2000). Groups in the lowlands may have had some access to upland resources (such as mule deer) from mountain ranges located 32 km away, and bighorn sheep would have been available at Valley of Fire. Jackrabbits and cottontails are also common in this area. Additionally, lowland Virgin Branch Puebloan groups also had access

Table 1.1: Summary of plant and animal species available in VBP area

Uplands	Lowlands
<i>Plants</i>	<i>Plants</i>
Pinyon (<i>Pinus</i> sp.)	Creosote (<i>Larrea tridentata</i>)
Juniper (<i>Pinus juniperus</i>)	Bursage (<i>Ambrosia dumosa</i>)
Agave (<i>Agave</i> sp.)	Beavertail (<i>Opuntia basilaris</i>)
Yucca (<i>Yucca</i> sp.)	Cholla (<i>Cylindropuntia</i> sp.)
Cholla (<i>Cylindropuntia</i> sp.)	Honey mesquite (<i>Prosopis glandulosa</i>)
Buckwheat (<i>Eriogonum</i> sp.)	Screwbean mesquite (<i>Prosopis pubescens</i>)
Globemallow (<i>Sphaeralcea</i> sp.)	
Groundcherry (<i>Physalis</i> sp.)	
Sunflower (<i>Helianthus</i>)	<i>Animals</i>
Ponderosa Pine (<i>Pinus ponderosa</i>)	Jackrabbits (<i>Lepus</i> sp.)
Sagebrush (<i>Artemesia</i> sp.)	Cottontail (<i>Silvilagus</i> sp.)
	Bighorn sheep (<i>Ovis canadensis</i>)
<i>Animals</i>	Desert tortoise (<i>Gopherus agassizi</i>)
Jackrabbits (<i>Lepus</i> sp.)	Variety of fish species
Cottontail (<i>Silvilagus</i> sp.)	
Mule deer (<i>Odocoileus hemionus</i>)	

to desert tortoise (*Gopherus agazzizi*). Fish also would have been available from the Muddy River and Virgin River although few (if any) works have looked at this resource, possibly due to preservation issues and recovery methods.

Cultural Context

Virgin Branch Puebloan groups inhabited these three districts – the St. George Basin, the plateaus, and the lowlands – from the Basketmaker II period to the Pueblo III period (roughly 300 B.C. to A.D. 1200). Archaic hunter-gatherer groups occupied this area before the Basketmaker periods, although less research has been done on this particular time period. Unfortunately, there are few dendrochronological and carbon-14 dates in the VBP area, so the chronology of this area remains unclear. At the moment, most archaeologists use a version of the Pecos Classification based on the Kayenta Anasazi, the Virgin Branch Puebloan people's eastern neighbors. Archaeologists are still modifying these dates and attempting to determine how well the Kayenta-based chronology holds up in the Virgin Region (Lyneis 1995). Additionally, this chronology is based almost exclusively on work done in the lowland VBP area as there has been little published research on the upland areas. A brief summary of the periods used in this chronology and their characteristics follows.

During the Basketmaker II period, which stretches from 300 B.C. to A.D. 400, sites include rock shelters and semi-subterranean pit structures. Likewise, storage pits were also semi-subterranean. Characteristic of Basketmaker II periods throughout the Southwest, ceramics were not produced during this time period. Additionally, the bow and arrow had not yet been introduced. Therefore, projectile points dating to this period are atlatl dart points (Lyneis 1995). By the Basketmaker II period, maize was present in the Virgin Branch Puebloan area, although

the nature of maize agriculture and people's reliance on this crop are debated (Lyneis 1995:208). At this time, Virgin Branch Puebloan sites were small and the basic social unit is believed to be the "coresidential group" which consists of one to three families (Lyneis 1995:210). While aggregation does occur, this trend of small social units continues up to abandonment of the region, and Lyneis notes that the term "village" is not applicable in this region (Lyneis 1995:210).

The Basketmaker III period (A.D. 400-800) is also characterized by pit structures. These structures are often accompanied by semi-subterranean storage features, and sites generally house about one to three families. This period also includes the introduction of new types of technology, notable ceramics and the bow and arrow. Atlatl dart parts are replaced by arrow points in the archaeological record. Gray Ware pottery, usually undecorated, was first produced during this time period. Painted wares were present at this time, but they were relatively rare (Buck and Perry 1999). Archaeologists often use changes in ceramic design (such as the introduction of corrugated wares and red wares) to construct chronologies for later periods (Lyneis 1995:209).

The Pueblo I period (A.D. 800-1000) also featured pit structures as habitations. The arrangement of these structures, however, changed in some ways from the previous period. While no pit structures have antechambers (typical of other Ancestral Puebloan groups), many do have benches and/or ventilators. Storage structures also tend to be arranged into an arc with habitation structures at one end of the arc, creating a more defined outdoor space. Lyneis (1995) interprets this as a precursor to the courtyards found at Pueblo II sites. Pueblo I period sites generally remained small, but the amount of storage at individual sites increased (Lyneis 1995:211). This increase in storage structures has been interpreted by Larson and Michaelsen

(1990) to signal an increase in the reliance on agriculture and agricultural intensification (as an adaption to drought and resource uncertainty).

Population size appears to increase slowly throughout time and reach its peak during the Pueblo II period. Lyneis (1996) writes that there may have been a slight increase in agricultural intensification during this time as evidenced by agricultural features like check dams and terraces on the Shivwits Plateau (see also Wells 1991). During the Early Pueblo II period (A.D. 1000-1050), pit structures and semi-subterranean storage features to continue to characterize sites which remain small (although there are exceptions such as the Mecca Site). In general, storage features are still arranged into an arc, but they are not set as deep in the ground (Lyneis 1995:213). In the Late PII period (A.D. 1050-1150), habitations in the form of pit structures begin to decrease (but never disappear), and people begin to construct above-ground habitation rooms. Habitation rooms also form a part of the arc of storage rooms, rather than simply being near the end, forming a defined courtyard. The courtyards remain small and do not reach the scale of large plazas. Courtyards were shared by a small coresidential group made of one to three families, which Lyneis (1995:216) terms a *courtyard group*. Finally, the middle Pueblo II period (ca. A.D. 1050) marks the height of the ceramic distribution network between the plateaus and the Moapa Valley (Harry et al. 2013).

In the Early Pueblo III period (A.D. 1150-1225), habitation and storage structures are arranged into a tighter curve, almost enclosing courtyards (such as at Mesa House and Three Mile Ruin) (Lyneis 1995:217). The ceramic distribution network involving Shivwits Plainware seems to collapse during the Pueblo III period (Harry et al. 2013). During this time, the population size also appears to decrease, and the area is eventually abandoned sometime in the mid-13th century (Allison 1991).

Ceramic Assemblages

The two areas included in this research, the lowland Virgin area and the plateaus, were connected economically through a ceramic distribution network. Research done by Harry et al. (2013) demonstrates that this distribution network was likely decentralized and reached its height in the middle Pueblo II period (around A.D. 1050). This exchange network involved the distribution of Moapa Gray Ware and Shivwits Ware ceramics from their production zones in the upland Virgin region west to the Moapa Valley and other lowland areas. The number of ceramics involved in this distribution is relatively small (when compared to some other exchange networks in the Southwest); however, because these ceramics were transported over 70 miles over difficult terrain and are found in abundance (often comprising more than half of the ceramics recovered from middle Pueblo II period sites) at lowland sites, this distribution network is impressive (Harry et al. 2013).

Furthermore, this distribution network is highly directional; Shivwits Ware and Moapa Gray Ware ceramics are found in abundance at VBP sites to the west. These wares are present at sites located to the east of their production zones, but they are not as common. The directionality of this exchange does not appear to be random and may be a result of the different environmental zones in the uplands and lowlands (Harry 2005; Allison 2000). Firewood, which is necessary for producing ceramics, is abundant on the plateaus but rare in the lowlands. On the other hand, agriculture would have been riskier on the plateaus where there are few water sources and the possibility of early frosts. Harry (2005) and Allison (2000) have both separately suggested that groups in the lowlands may have been trading for ceramics produced in the uplands for food (or

other resources such as salt and cotton) as agriculture was less risky along the Muddy River and Virgin River. Further research is needed to address this issue more fully.

Moapa Gray Ware

Moapa Gray Ware is characterized by its olivine temper; in general, the temper in these types of ceramics is approximately 65% olivine. Orthopyroxene and clinopyroxene, generally account for the remaining percentage of the temper, but other xenoliths are found. The paste is usually light in color and crushed sherds are seldom used for temper, distinguishing it from Shivwits Wares. This ware is found in the lowlands starting in the Basketmaker II period and up to the late Pueblo II period, with the highest quantities (at least 30% of the gray ware ceramics) being found during the middle Pueblo II period (Lyneis 2008). Moapa Gray Ware is named for the Moapa Valley where it was first identified; however, the likely production zone is on the plateaus. Specifically, Margaret Lyneis (2008) has identified the area around Mt. Trumbull (on the Uinkaret Plateau) as a probable production area. Interestingly, it is found in very low quantities east of its production area. Moapa Gray Ware vessels recovered from the lowland region include plain, painted, and corrugated vessels, and are found in both bowl and jar forms.

Shivwits Plain Ware

Shivwits Wares include Shivwits Plain and a corrugated variety. Shivwits Plain Ware is often recognizable due to its dark paste and color which can range from reddish brown to dark gray. Shivwits Wares are tempered with crushed sherds made from multiple types of ceramics such as Moapa Gray Ware and Tusayan Gray Ware, as well as white wares. This means Shivwits Plain Ware ceramics sometimes do contain olivine, but the large amounts of sherds in the temper makes them identifiable from Moapa Gray Wares in which sherd temper is rare. Like Moapa

Gray Wares, Shivwits Plain Ware is also found throughout the Moapa Valley up to the Late Pueblo II period, and again seems to reach its peak during the middle PII period (Lyneis 2008). Work by Harry et al. (2013) has identified the southern portion of the Shivwits Plateau as the area where it was produced using neutron activation analysis (NAA) and petrographic analysis. Shivwits Ware vessels recovered in the lowland region consist nearly entirely of large, wide-mouthed unpainted jars.

Tusayan Gray Ware

Tusayan Gray Ware refers to undecorated and painted ceramics produced by both the Kayenta and Virgin Branch Puebloan area. This ware is separated into two series based on production area; the Tsegi Series is used to designate ceramics made in the Kayenta area, while the Virgin Series includes ceramics made in the Virgin area. Tusayan Gray Wares are sometimes difficult to classify based on the range of tempers used to make them. These ceramics are tempered with quartz sand or a mixture of quartz and feldspar sands (Lyneis 1992:41), and colors vary from dark gray to brown to reddish brown (Harry et al 2013:387-8). Based on the types of minerals and sands present in these ceramics, Lyneis (1992:43) concludes that plain Tusayan Gray Ware ceramics could have been produced in both the Moapa Valley and Virgin River Valley. At Main Ridge, Tusayan Gray Ware and Tusayan White Ware ceramics are incredibly common, making up 61.5% of the ceramic assemblage (Lyneis 1992:41).

Chapter 2: Research Design

Research Questions

Compared to much of the American Southwest, little archaeological research has been done in the Virgin Branch Puebloan (VBP) area. Furthermore, most of this research has been performed in the lowland areas along the Virgin River and the Muddy River, meaning that archaeologists often use data from the lowlands to represent the entire VBP area since there is not as much information on the upland area. The upland area (including the Shivwits Plateau), however, have a dramatically different environment with different climatic conditions and wild resources. The lack of research on the upland VBP area means current models of diet and subsistence strategies may not be representative of local adaptations to environmental differences. For this study, I looked at organic food residues from both upland and lowland sites to determine the types of foods cooked, stored, or prepared in those vessels. These data were used to answer the following three research questions:

1. What do the residues suggest about the VBP diet and subsistence strategies?

In general, VBP diet is believed to rely on a variety of wild plant and animal resources along with domesticates (Allison 2000). Maize (*Zea mays*) was the most common domesticate, but beans (*Phaseolus* sp.) and squash (*Cucurbita* sp.) were also cultivated. Wild resources available in the lowlands include gopher tortoise (*Gopherus agassiz*), mesquite (*Prosopis* sp.), and certain fish species. In the uplands, large game such as mule deer (*Odocoileus hemionus*) and bighorn sheep (*Ovis canadensis*) are more common. Some resources are available in both areas including small mammals like jackrabbits (*Lepus* sp.) and cottontails (*Sylvilagus* sp.) and some cactus species. Perhaps due to the limited amount of research in this area, archaeologists working in the

VBP area disagree about people's degree of dependence on maize agriculture and the role of wild foods in VBP diet and subsistence strategies.

Some researchers argue that VBP were heavily dependent on maize agriculture starting in the Basketmaker period. For example, Martin (1999) concludes that VBP people were fully dependent on maize agriculture from the Basketmaker II period through the Late Pueblo II period based on stable carbon and nitrogen isotope ratio analysis on VBP skeletal remains. He argues this high degree of dependence on maize remained stable throughout time and that while VBP groups did use wild resources, they would have made up a very small part of the diet. Furthermore, hunting and gathering activities would have been timed to fit into the agricultural schedule rather than vice versa. However, stable carbon and nitrogen isotope analysis may not be the best technique for analyzing people's degree of dependence on maize agriculture as it only shows low dependence or high dependence on the resource according to Hard, Mauldin, and Raymond (1996).

Similarly, McFadden (1996) argues that VBP groups were primarily agriculturists. This is in part based on the abundant storage facilities associated with maize at Basketmaker sites. He downplays the role of wild foods by arguing that a mixed diet does not equate to a mixed subsistence economy. Rather, subsistence strategies revolved around maize agriculture: "It is suggested here that, *regardless of dietary mix, it was the practice of agriculture that structured – not the procurement of game and wild seeds*" (McFadden 1996:21). Wild food resources may have been eaten, but they were not as important to the social organization, subsistence strategies, and structure of VBP society as maize agriculture.

Other researchers argue that VBP groups became more dependent on maize agriculture over time. Larson and Michaelsen (1990) write that a drought occurring ca. A.D. 1000-1015, coupled

with increasing population size, led to the intensification of agriculture. Similarly, Larson (1996) argues that increasing population size would have stressed wild resources, leading to increased reliance on domesticates. He argues this can also be seen in the settlement patterns along the upper and lower Muddy River as later sites are located closer to better agricultural land. Note that both these articles focus on the lowland VBP area and ignore the upland area. Allison (1991) also critiques Larson and Michaelsen's 1990 article, stating the climatic change and population growth in the VBP area may not have been as dramatic as they depict. In that case, people may not have been as reliant on maize agriculture or perhaps the transition was slower than depicted by Larson and Michaelsen (1990).

Other archaeologists argue that wild foods played an important role in VBP diet and subsistence strategies. In their analysis of Antelope Cave, a VBP site in northwestern Arizona containing large quantities of jackrabbit (*Lepus californicus*) and cottontail (*Sylvilagus* sp.) faunal remains, Fisher, Janetski, and Johnson (2013) stress the importance of hunting and small mammals as part of the VBP diet. Fisher and Johnson (2014) write that Antelope Cave was used seasonally by multiple groups who engaged in communal jackrabbit hunts. The rabbits were roasted, the bones were broken to retrieve the marrow, and then the bones were stewed. roasting the rabbit and stewing the bones. Large and small mammal faunal remains, as well as maize cupules, were also recovered near Hurricane, Utah at a BMIII VBP site. Buck and Perry (1999) conclude the site's inhabitants relied on both maize agriculture and hunting. Likewise, Harry and Watson (2010) conclude that VBP groups living at Pueblo Grande de Nevada in southern Nevada relied significantly on agriculture; however, they also note the site's inhabitants used a wide variety of wild resources including cheno-am, tansy mustard, tortoise, waterfowl, jackrabbits, and bighorn sheep.

Another issue with determining VBP diet and subsistence strategies is that there may be regional variation due to environmental, geological, or climatic factors. As Harry (2014) points out, maize agriculture is much riskier on the Shivwits Plateau than in the Moapa Valley, meaning groups in the uplands probably supplemented their diet with wild resources. Allison (2000:182) investigated modern-day climatic records for growing maize in these two areas and discovered there were important differences between the two areas: “In particular, they suggest that maize dry-farming would have been risky in the uplands, due mostly to variation in precipitation during the growing season and around the time that maize plants would have been silking.” There are of course risks to growing maize anywhere, but dry-farming on the Shivwits Plateau was certainly riskier due to the short growing season, early frosts, and lack of permanent water sources.

Furthermore, Sullivan (1992) notes that previous research on subsistence strategies and diet may significantly underestimate Puebloan groups’ reliance on wild foods, particularly pinyon nuts. In part, this may be due to processing wild foods away from habitation sites. Sullivan’s work focuses on large fire-cracked rock piles located in Kaibab National Forest in northern Arizona. He argues these sites were likely used as work areas to roast pinyon cones in order to harvest the nuts. The nuts were then processed using groundstone artifacts present at the site, rather than bringing the groundstone and other tools to the harvesting site (Sullivan 1992:225). If pinyon nuts were prepared as Sullivan suggests, there may be little evidence of them in the archaeological record at habitation sites. Although Sullivan’s work focuses on Kayenta Anasazi sites, a similar practice of preparing wild foods away at work areas could affect the types of remains entering the archaeological record at VBP sites. For example, we may underestimate the importance of rabbits in VBP diet if they were processed away from habitation sites, as Fisher,

Janestska, and Johnson (2013) argue occurred at Antelope Cave (see also Fisher and Johnson 2014).

In summary, there is no consensus on VBP diet and subsistence strategies. It is generally agreed that maize was an important part of VBP diet, but the role of wild foods is unclear. Evidence of residues from mammals and fish, in particular, would suggest that hunting also played an important role in their subsistence strategies. The GC-MS techniques I use for this research can only be used to infer broad categories of foods, so it is currently not possible to distinguish between wild plants and domesticated plants. For this research, I focused on the relative amounts of residues from plants versus mammals, and whether or not residues from fish are present.

2. Are there differences in the types of residues found at upland sites compared to lowland sites?

Since the Shivwits Plateau has only recently been studied from an archaeological perspective, little is known about how VBP diet and subsistence strategies differ between the uplands and the lowlands. These two areas have different environmental conditions and thus, different types of wild plant and animal resources. This in turn could affect the types of residues present in the ceramics from upland and lowland sites. For example, groups living on the Shivwits Plateau would have had access to pinyon nuts. Pinyon nuts are high in protein and fat, but the trees only grow at higher elevations and would not have been found in the lowlands. Additionally, large mammals, such as big horn sheep and mule deer, are more common on the Shivwits Plateau than in the lowlands. Groups living in the Moapa Valley, on the other hand, would have had access to riparian resources along the Muddy River. Food resources specific to

this area include fish, waterfowl, and gopher tortoise, as well as mesquite which generally grows at lower elevations.

Although these two areas have different environments, there is some overlap in the types of resources used. As previously mentioned, maize agriculture was riskier on the Shivwits Plateau than in the Moapa Valley (Harry 2014), but it was not impossible; maize will almost certainly be present in the residues from both upland and lowland VBP sites. Other domesticates that have been found in both areas include squash and beans. Likewise, jackrabbits and cottontails are common throughout the VBP areas and people living in both areas probably used these resources. Thus, I expected that there would likely be some overlap in the types of residues present in ceramics from upland and lowland VBP sites.

There are four possible scenarios when looking for differences in the types of organic residues present in ceramics from upland and lowland sites:

(1) There are no differences in the types of residues and there are no non-local foods present in the samples. This would suggest VBP groups in both areas were relying on the same types of resources, rather than wild resources unique to that area (such as fish in the lowlands). This scenario would fit with a model of VBP diet and subsistence strategies in which people were heavily dependent on agriculture as maize and other domesticates could be grown in both areas despite environmental differences. In this scenario, wild resources would play a very small role in VBP diet and subsistence strategies. Additionally, it could also suggest a pattern of exchange or interaction that allows groups in both areas to use the same resources. For example, if upland groups procured maize from the lowlands to supplement their own agricultural practices, the residues would be similar for both areas.

(2) There are differences in the type of residues present in the upland and lowland samples, but all of the residues originated from foods common to both areas. This type of difference could be a result of differences in diet and subsistence strategies in the two areas with groups in the uplands and lowlands placing more importance on different types of foods. One of the methods for analyzing the residues uses ratios of fatty acids to identify six broad categories of foods – roots, seeds and nuts, greens, mammals, berries, and fish (see Eerkens 2005). An example of this scenario would be finding mainly residues from roots in the lowlands and seeds/nuts from the uplands. These two categories of foods would be available in both areas, and it is not possible at this time to narrow down specific species of plants represented in the residues. In our example, perhaps lowland groups relied more on the root of the agave plant, while upland groups relied more on the seeds.

Alternatively, the different types of residues could be a result of the different foods available due to seasonality. The residues present in ceramic vessels are believed to be from the first few uses (Eerkens 2005) – these residues are absorbed into the walls of the vessel and block other particles from entering the vessel's pores. This pattern of residues could possibly be representative of when those particular vessels were first used, rather than differences in the overall types of foods used between these two areas. Sampling multiple sites and vessels would help negate this possibility.

(3) There are differences in the types of residues found at upland and lowland sites, and some of the residues represent foods only available in that area. An example of this scenario would be finding residues from fish in ceramics from the Moapa Valley, but not in the uplands. Finding significantly higher amounts of residues from large herbivores (e.g. mule deer and bighorn sheep) in the uplands than the lowlands would also be an example as large herbivores

are more common in the uplands. This would suggest there is no universal model for VBP diet; rather, there were regional variations in diet and subsistence strategies based on the local environment. As previously mentioned, data on diet and subsistence strategies from the lowlands are often used to infer practices in the upland VBP area as there has not been as much research in the uplands. This scenario, however, would suggest that VBP data on the lowlands is not applicable to the uplands.

(4) Non-local foods are represented in the residues in samples from either area. Examples of this scenario would include finding fish residues in the ceramics on the Shivwits Plateau or large amounts of large herbivore residues in the lowlands. Unfortunately, zooarchaeological and flotation data have not been able to help us confirm that VBP groups were using some of these environmentally specific resources, such as pinyon or fish. Pinyon nuts are high in protein and fat, so it seems likely that upland groups would use this resource, but none of the macrobotanical data from Granary House or Site 232 on the Shivwits Plateau contained traces of pinyon. As Sullivan (1992) writes, this may be due to how pinyon nuts were prepared – if they were prepared offsite, then it is unlikely for pinyon remains or debris from processing the nuts to enter the archaeological record at these habitation sites.

The consumption of fish has also been difficult to detect. Several fish bones were recovered from Catclaw Cave along the Colorado River in northwestern Arizona (roughly 15 miles south of the Hoover Dam), but the dates for the cave's occupation are uncertain (Wright 1954). No faunal remains from fish, however, were recovered during the 2005 field work at Main Ridge or additional excavations in 2006 at House 20 (both sites are part of the Pueblo Grande de Nevada complex in southern Nevada) (Harry et al. 2008; Harry and Watson 2010). There are several reasons why fish remains may not be present in the archaeological record at these sites: (1)

people simply were not eating fish, (2) taphonomic processes resulted in the destruction of the remains, and (3) recovery methods were insufficiently fine-grained to detect the remains. Fish bones are fairly small and fragile, so it is possible that they may be overlooked when looking for faunal remains.

Finding non-local wild foods in the ceramics would not only demonstrate that VBP relied on wild foods, but it would also suggest that wild foods played an important role in VBP subsistence strategies as groups were engaging in activities or relationships in order to procure these resources. There are a few different ways VBP groups may have gained access to these resources: direct procurement, exchange, and communal gatherings.

Direct procurement refers to groups travelling to the source of the resource and harvesting or hunting it themselves. The Moapa Valley and the Shivwits Plateau are separated by over 113 km. Travelling between the two areas and bringing back resources would have been a difficult task. of harsh terrain. VBP groups living in the Moapa Valley may not have had to travel quite that far; the Virgin Mountains are located approximately 30 km to the east and could have been used by lowland groups to gain access to upland resources (Harry and Watson 2010). If VBP groups were directly procuring non-local resources, it seems more likely that they would exploit different environmental areas that were closer, rather than travelling directly to either the Moapa Valley or Shivwits Plateau.

Another option for gaining access to non-local resources is food exchange. There is evidence that the Virgin Branch Puebloan groups on the Shivwits Plateau were engaging in a regional ceramic distribution network (Harry et al. 2013), indicating there was contact and existing cooperative relationships between groups living in the upland and lowland areas. Allison (2000)

suggests the groups in these two areas were engaging in a mutualistic exchange relationship (in which both groups benefit from the relationship) exchanging maize for firewood; maize agriculture was less risky in the lowlands, while firewood for making ceramics was plentiful in the uplands. It is possible that other types of food may have played a role in the existing exchange relationship. Unfortunately, it is not possible at this time to identify the presence of specific types of plant species in the residues using gas chromatography and mass spectrometry. It is, however, possible to detect and identify residues from fish and large mammals.

A third option is that people brought food with them for communal gatherings. Allison (2000) suggests upland and lowland groups may have gathered in the Moapa Valley for harvest festivals:

Festivals lasting a week or two in late June or July could have provided an important source of food at a critical time for some of the people living on the Shivwits and Uinkaret Plateaus, and would have allowed them to return home in time to harvest their crops, which would not produce the first edible green corn until early August. Upland people attending such festivals could have brought pottery, or other upland products (such as deer skins or tools made from ungulate bones or antlers) to trade [Allison 2000:214].

In this case, it is different from an exchange relationship in the sense of groups frequently trading throughout the year specifically for certain goods; rather, the interactions at these types of festivals or gatherings would be more seasonal.

3. Were ceramic vessels in the VBP area used differently based on ware?

For this research, I sampled three types of undecorated, utilitarian wares: Shivwits Ware, Moapa Gray Ware, and Tusayan Virgin Series. There has been considerable research on how vessel form and function relate, and many of these studies rely on ethnographic or ethnoarchaeological data. In a study on modern Kalinga groups, for instance, Skibo (2013:77) found that vessels with different forms served different functions; pots used to cook vegetables and meats were shorter with flared rims and large openings, while rice-cooking pots were taller with smaller openings and less flared rims. Likewise, Eerkens (2005:97) found that different types of pots in the western Great Basin were used to cook different types of foods – “In the final analysis, it appears that pots were not all-purpose or generalized tools, but were constructed with specific uses in mind.” By comparing the attributes of the vessel’s rims with the organic residues present in the vessels, Eerkens found that vessels used to boil or stew meat usually had rims curved to minimize evaporation and heat loss, while vessels used to cook seeds had more open orifices to promote evaporation and prevent damage to the pot from heat buildup.

Much like the form of a ceramic vessel, the type of temper used to make the vessel can also affect its functional properties. Skibo (2013) notes that the type of temper used when making a pot can affect several performance characteristics such as thermal shock resistance, permeability, weight, heating efficiency, and impact resistance. For example, vessels with high levels of minerals in the temper are more permeable allowing the vessel’s contents to cool more effectively (Skibo 2013:40). All three of the wares sampled for this study are made with different tempers, and Anderson (2011) demonstrates that this does affect their functional properties. Anderson performed experiments on Shivwits Ware, Moapa Gray Ware, and Tusayan Virgin Series ceramics to test their thermal shock resistance, strength, and heat transference. She found that Tusayan Virgin Series ceramics performed worse overall in all three categories. Tusayan

Virgin Series ceramics were more susceptible to micro-fissures and cracks because they are tempered with smooth, round quartz grains compared to the more jagged olivine nodules and sherd pieces. She also noted that olivine tempered ceramics were more consistent in the time it takes to heat water in the vessel both to a simmer and a boil compared to both sand tempered and sherd tempered ceramics.

As these types of vessels had different functional properties, it is possible that they may have served different functions. For example, both olivine tempered and sherd tempered ceramics were more resistant to thermal shock than sand tempered ceramics (Anderson 2011). Perhaps then, these types of ceramics would be used more frequently to boil foods or cook them at higher temperatures, such as boiling lily bulbs or stewing jackrabbit bones (as hypothesized at Antelope Cave – see Fisher and Johnson 2014). If the wares were used specifically to prepare different categories of foods, this may show up in the types of residues absorbed into the walls of the ceramics. This could also suggest a cultural association between types of foods areas, which may be the result of functional attributes (i.e. these pots are better for cooking these foods), or associations between the origins of the foods and the origins of the pots.

Chapter 3: Methods

Gas chromatography and mass spectrometry (GC-MS¹) was used to identify the types of lipids present in ceramics from both upland and lowland sites, and to provide more data on VBP diet. These data were used to infer broad categories of food which were likely cooked, stored, or prepared in those ceramic vessels. Plant and animal residues are made of a wide variety of lipids and other chemicals compounds; one of the advantages of GC-MS is that it enables archaeologists to separate and identify specific these chemical compounds (Heron and Evershed 1993). In some cases, archaeologists are able to identify biomarkers, chemical structures or compounds that can be matched to specific plant or animal products (Evershed 1993; Evershed 2008). For example, Washburn et al. (2013) identified *Theobroma cacao* in ceramic vessels from Alkali Ridge in southeastern Utah based on the presence of theobromine. In most cases, however, this type of residues analysis is limited to identifying broad categories of foods, such as fish, mammal, seeds and nuts, or roots (see Eerkens 2005 for example).

Gas chromatography and mass spectrometry can also detect foods that may not be detected using other methods such as floats, pollen samples, or faunal remains. The types of foods that enter the archaeological record and can be detected using these methods depends on how well they preserve and how they were prepared. Munson et al. (1971:427) identifies three categories of plant remains based on their likelihood of preservation (in decreasing order):

(1) “The first group includes those foods which have rather dense, inedible parts” –

Foods in this category, including maize cobs, are highly likely to be carbonized which also helps increase their likelihood of preservation.

¹ Also written as *GC/MS* in some literature. The abbreviation *GC-MS* will be used throughout for consistency.

- (2) “The second group also includes plant foods which are somewhat dense but which are normally ingested in their entirety” – Small seeds such as amaranth seeds, maize kernels, chia seeds, and squash seeds can preserve given appropriate conditions.
- (3) “The final group includes non-dense plant foods with a high water content” – This category of foods includes tubers and greens which are unlikely to preserve.

Foods such as desert lily tubers or highly unlikely to preserve, making it difficult to find evidence of them during excavation and in floats. This biases our understanding of VBP diet and subsistence strategies by emphasizing those foods which preserve well, such as maize. Greens and roots can be preserved if they are absorbed into the pores of ceramic vessels. Using GC-MS to analyze these residues can help us detect these and other types of foods which may not be preserve well and gain a more comprehensive understanding of VBP diet and subsistence strategies.

Another advantage of using GC-MS is that it allows us to directly identify foods VBP groups were cooking, storing, or preparing in ceramic vessels. Other methods rely on inferring the types of foods that were prepared indirectly. For example, a vessel’s form can sometimes be used to infer the types of foods it was used to cook. As noted, Eerkens (2005) found that Great Basin vessels used to boil or stew meat usually had curved rims, while vessels used to cook seeds had more open orifices. Likewise, Hard et al. (1996) argue that mano size and people’s degree of dependence on maize are related. Better understanding the relationship between artifacts’ form, size, and function is a helpful line of evidence, but these methods do not provide direct evidence that certain foods were actually present in the artifacts like GC-MS does. This technique has been performed at very few sites in the Virgin Branch Puebloan area. This type of analysis will

provide another type of data to supplement the existing body of work and help us better understand VBP diet and subsistence strategies.

Residue Analysis in Archaeology

In order to understand the role of ceramics in food consumption, archaeologists use a variety of techniques such as use-wear studies, ethnographic analogy, and ethnoarchaeology. A more recent set of techniques focuses on analyzing and identifying organic residues left in or on ceramic vessels. Heron and Evershed (1993:260) cite Alfred Lucas's *Ancient Egyptian Materials and Industries* (originally published in 1926) as one of the first archaeological studies to look at organic residues; however, the study of organic residues in archaeology did not become popular until more recently. Thanks to technological advances in the 1970s, archaeologists today employ a number of methods to help identify and analyze organic residues in a variety of archaeological contexts. Ceramics are by far one of the most common targets of residue analysis (Evershed et al. 2002:660), but other studies have successfully detected and analyzed residues present on lithics, fire-cracked rock, and floors (e.g. Middleton et al. 2010, Buonasera 2007).

Residue analysis is not a specific technique, but refers to a number of methods used to examine chemical remains left in archaeological contexts. For example, stable isotope analysis is used to compare ratios of carbon isotopes and nitrogen isotopes (frequently in skeletal remains). This allows archaeologists to compare the types of plant residues (usually C₃ versus C₄ plants) present in the sample. Two types of spectroscopy, infrared spectroscopy (IR) and nuclear magnetic resonance spectroscopy (NMR), have also been used with some success. Other methods like Curie-point pyrolysis mass spectrometry (CuPy-MS) and Curie-point gas chromatography/mass spectrometry (CuPy-GC/MS) use pyrolysis to break down large molecules into smaller ones which can then be separated and analyzed.

Various types of chromatography have been used to separate chemicals found in residues. These include thin layer chromatography (TLC) and high-performance liquid chromatography (HPLC), as well as CuPY-GC/MS mentioned above (Heron and Evershed 1993). Techniques using gas chromatography (GC), sometimes coupled with mass spectrometry (GC-MS), have been particularly popular in archaeological studies of organic residues (Heron and Evershed 1993). A GC-MS instrument generally has three main parts: a gas chromatograph, a mass spectrometer, and a data system. The gas chromatograph oven contains a column where chemicals in the sample are separated as the mobile phase passes through the stationary phase. In GC-MS the mobile phase is a gas (often hydrogen, helium, nitrogen, or argon). This process is similar to another type of chromatography, liquid chromatography (LC), which uses a liquid rather than a gas for the mobile phase. Molecules leave the column at different speeds and their retention times are recorded by the data system. The mass of these molecules are identified by the mass spectrometer, producing a mass spectrum and aiding identification (Grob and Barry 2004).

Organic Residues and Lipids

Organic residue is a very broad term and archaeologists have used this term to refer to a wide variety of substances: “The term *organic residue* has been used widely by archaeologists and archaeologists to describe a variety of amorphous organic residues found at archaeological sites” (Heron and Evershed 1993:240). This definition is opposed to seeds, bones, or charred corn cobs, for instance, which have a defined shape (Heron and Evershed 1993:249). Not all organic residues are food residues; they can also include non-food products such as tar, pitch, wax, and resin. Several processes will leave residues on ceramic vessels: cooking, brewing, tanning, dyeing, preparing foods, etc. Sometimes these residues are visible to the naked eye, such

as soot on the outside of a pot or a visible scum line on the inside of a vessel (Heron and Evershed 1993:250). However, many residue analysis techniques focus on the identification of absorbed residues that cannot be detected with the naked eye. Due to the porous nature of ceramic vessels, organic residues can be absorbed into the wall of a ceramic vessel during use, especially during cooking (Evershed 1993; Heron and Evershed 1993). Heron and Evershed note, however, that residues may not be absorbed during the storage of dry goods such as grains or seeds.

A number of different molecules are present in organic residues including carbohydrates, proteins, lipids, and nucleic acids. This study looks specifically at lipids. Malainey (2011:201) defines lipids as “a broad category of compounds that are insoluble in water.” Lipids are one of the most common targets for residue analysis; they are well suited for archaeological investigations because they are present in a variety of residues and they tend to preserve better than other types of molecules.

Lipids can be found in a wide range of archaeological contexts in part due to their composition. Generally, lipids are made up of chains of carbon, hydrogen, and oxygen which allows for a great variation in shape and structure thanks to carbon-carbon bonds (Evershed 1993:75). This class of molecules includes waxes, triglycerides, phospholipids, sterols, and fatty acids, and they are found in a large number of plant and animal tissues:

The prominence of animal fats among the solvent-soluble components of various organic residues encountered at archaeological sites is consistent with their wide range of potential uses in antiquity, i.e., diet, art materials, lubricants, illuminants, binders, waterproofing agents, bases for cosmetics, ointments, and perfumes, use

in religious rituals and burials practices, varnishes, glues, polishes, etc. [Evershed et al. 2002:660].

In addition to being found in a variety of plant and animal residues, lipids are suitable molecules to study using residue analysis because they preserve fairly well. Lipids are more likely to withstand decay and contamination than other types of molecules such as carbohydrates and proteins (Heron and Evershed 1993; Evershed 1993). Although the depositional conditions (e.g. pH, temperature, amount of water, etc.) do affect the preservation of lipids, contamination from the soil in the depositional context is generally minimal (Evershed 1993; Malainey 2011). This is usually credited to lipids being hydrophobic:

This showed that there was minimal post-burial contamination due to lipids migrating into potsherds from the surrounding soil. This was explained in terms of the hydrophobic nature of lipids, which limits their solubility in groundwater, hence reducing the likelihood of them migrating into (or out of) potsherds by dissolution and diffusion.” [Charters et al. 1993:211; see also Heron and Evershed 1993].

Lipids that are absorbed into the pores of ceramic vessels are even more likely to preserve because they are shielded from water, light, oxygen, and microorganisms (Heron and Evershed 1993; Evershed 1993; Malainey 2011). In this study, I used GC-MS to analyze lipids absorbed into the pores of ceramics recovered from upland and lowland VBP sites.

Sampling Strategy

Thirty ceramics representing three ceramic wares and two environmental areas were analyzed for this study. Of these thirty samples, each environmental zone (i.e. the Shivwits Plateau and the Moapa Valley) is represented by fifteen samples. All three ceramic wares

(Moapa Gray Ware, Shivwits Ware, and Tusayan Virgin Series) are undecorated plainwares and are represented by ten samples each. See Table 3.1 for a breakdown of the samples used in this research.

Table 3.1: Summary of sample size based on ware and site

	Shivwits Plateau	Moapa Valley
Moapa Gray Ware	5	5
Shivwits Ware	5	5
Tusayan Virgin Series	5	5

According to Malainey (2011), ceramics targeted for residue analysis should be collected in the field, unwashed, and only handled with gloves. Water-soluble residues may be lost during washing. These ceramics were washed with water and labelled by previous researchers; however, Malainey (2011) also notes that washed sherds can still be used for lipid residue analysis as lipids are not soluble in water. Additionally, using ceramics from collections allowed for easier sampling and multiple tests if necessary.

The ceramics used in this study were sampled based on three criteria: (1) ceramic ware, (2) location of sherd on original vessel, and (3) sherd size.

1. Ceramic Ware

I examined three types of unpainted, undecorated ceramic wares: Moapa Gray Ware, Shivwits Ware, and Tusayan Virgin Series. Unpainted wares were selected for the analysis as they were more likely than painted ceramics to have been used in general, day-to-day cooking,

storage, and food preparation activities than painted or decorated wares. Thus, the residues left in these types of wares may better represent the range of foods prepared or stored at these sites.

Additionally, the lack of a glaze or slip may facilitate the absorption of lipids into the pores of the vessel. A description of the ceramic wares sampled for this research can be found in Chapter 1.

2. Location of sherd on original vessel

The location of the sherd on the original ceramic vessel can play a role in the concentration of residues left on its surface. During cooking (specifically boiling foods), the highest concentration of residues tends to accumulate toward the rim of the vessel, while base sherds usually have the lowest concentrations (Malainey 2011; Charters et al. 1993). Charters et al. (1993) note two possible reasons for this pattern. First, lipids (such as fats and oils) are less dense than water, so they tend to rise to the surface (see also Malainey 2011). Second, the heat from being placed in or near a fire may cause any lipids in base sherds to degrade.

For this research, I selected sherds from the body of the vessel. As Malainey (2011) points out the pattern of higher concentrations of residues near the rim is also affected by the amount of liquid placed in the vessel and how much boils off over time, leading to residues being found in the top third of the vessel. Body sherds still contain high enough concentrations of residues that can be used for analysis (Malainey 2011) and they are ubiquitous for all three types of wares and sites included in this research. Additionally, using body sherds (rather than rims or base sherds) for my analysis means I destroyed a smaller percentage of that particular sherd type.

3. Sherd size

Preference was given to larger sherds in the sampling process as a result of the residue analysis process. In order to analyze the sherd using GC-MS, an approximately 1x1 cm sample is cut from the sherd and destroyed. Using larger sherds allows for further analysis if needed and future studies using the same samples.

In summary, I sampled body sherds from three different types of ceramic jars with preference for larger sherds. I sampled five sherds from each ceramic ware, equaling 15 sherds from Granary House and 15 sherds from the Muddy River Survey for a total of 30 samples.

Site Descriptions

This study looks at Virgin Branch Puebloan sites from two different environmental zones, the Shivwits Plateau in the upland VBP area and the Moapa Valley in the lowlands. All sites date approximately to the Middle PII period.

Lowland Sites

The first set of sites, MRS 73-5 and MRS 73-34, are located in the lowland area of the Moapa Valley (as shown in Figures 3.1 and 3.2). These sites were chosen as they have abundant ceramics, allowing for multiple tests and future research on the same collections. All ceramics samples from the Muddy River Survey are on loan from the Department of Anthropology at the University of Nevada, Las Vegas.

MRS 73-5. This site was investigated in 1973 by the University of Nevada, Las Vegas as part of the Muddy River Survey. The survey, led by Dr. Claude Warren and recorded by Lawrence Alexander, covered about 3.4 km along an elevated terrace (sometimes called “Anasazi Bench” or “Sand Bench”) on the east edge of the Muddy River. It included over 70 sites ranging from the PI period to the PIII period. Unfortunately, many of these sites have been vandalized. Surface

collections were made at most sites, although the collection strategies varied widely between sites – e.g. some sites were divided into 10 x 10 foot units, while others were divided into larger areas. However, Allison (2000) notes the collection is probably representative of the sherds present at these sites as all types of sherds (including plain and corrugated sherds) were collected and there are few decorated sherds.

MRS 73-5 consists of three components (labeled A, B, and C) surrounding a courtyard. A modern-day car track cuts across the middle of the site and bisects components A and B. Component A, on the north edge of the site, is comprised of several small adjoining rooms constructed in a 15-degree arc and two circular depressions. Component B is located on the south side of the site and contains five small contiguous rooms. This component was heavily vandalized. The site notes also mention that small bone fragments were found in one of the rooms, indicating a possible vandalized burial. Component C is located on the east side of the site and contains three small circular rooms – only one of which was vandalized – and a sub-rectangular room described as a granary (Muddy River Survey field notes).

MRS 73-34. This site is about 75 feet in diameter with one large circular structure and several other smaller structures. A burial was recovered from the large circular structure. The smaller structures were heavily vandalized, and the shape of these structures could not be determined at the time of the survey. The site notes point out that more structures may be present but are covered by sand. The site also contained a large concentration of ceramics, mostly plain ware ceramics with some corrugated and painted wares (Muddy River Survey field notes).

Figure 3.1: Map showing location of Muddy River Survey and surrounding area (Allison 2000:38)

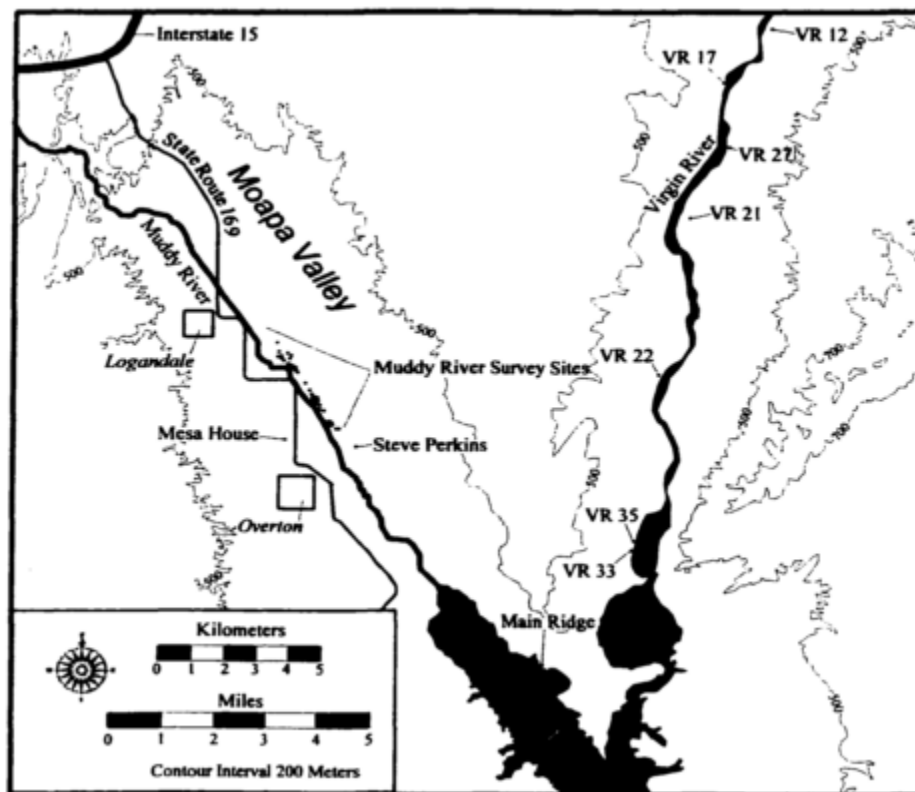
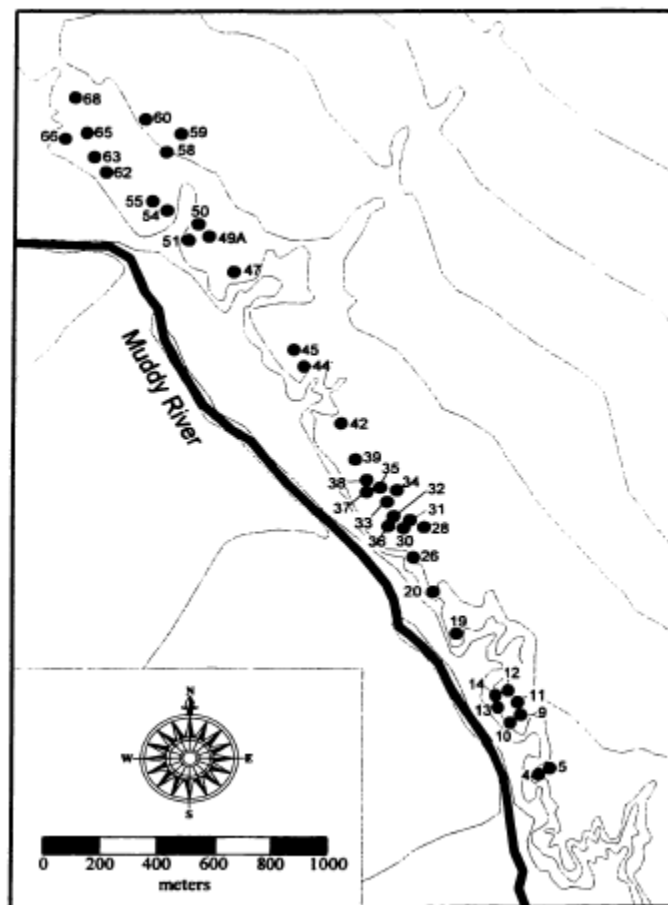


Figure 3.2: Map showing location of Muddy River Survey sites including MRS 73-34 and MRS 73-5
(Allison 2000: 41)



Upland Sites

The second set of sites, Granary House (AZ:A:14:46) and Site 232 (AZ:A:14:232) (shown in Figure 3.3) are located on the southern portion of the Shivwits Plateau. Of the sites on the Shivwits Plateau that have been investigated, very few date to the Middle PII period. These two upland sites were chosen as they both date to the appropriate time period for this analysis. These samples from both Granary House and Site 232 are on loan from the collections facilities at LAKE.

Granary House (AZ:A:14:46). This four-room farming hamlet was investigated in 2006 and 2010 by the University of Nevada, Las Vegas (UNLV), Lake Mead National Recreation Area (LAKE), and Parashant National Monument (PARA) as a part of the Shivwits Research Project led by Dr. Karen Harry. This site dates to the middle Pueblo II period (ca. A.D. 1000-1100) based on the percentage of corrugated sherds – only 5% of the ceramics recovered are corrugated. Additionally, two pieces of wood from the site returned radiocarbon dates of A.D. 980-1170 and A.D. 950-1040 which are consistent with the middle Pueblo II period date from the ceramic analysis. A variety of wild and cultivated plant remains were found at the site, including a charred cupule, cheno-am, goosefoot, and small grass seeds. Likewise, pollen samples contained pollen from maize, prickly pear, wild buckwheat, chenopodium, and wild grasses. This suggests the site's occupants relied on both agricultural and wild food resources (Harry n.d., Granary House).

Site 232 (AZ:A:14:232). This site was excavated in 2011 by the University of Nevada, Las Vegas, PARA, and LAKE. Site 232 is a small hamlet consisting of several rooms and an artifact concentration. The ceramic assemblage from Site 232 indicates there were likely two

Figure 3.3: Location of Site 232 (AZ:A:14:232 and Granary House (AZ:A:14:46)
(Harry n.d., Site 232)

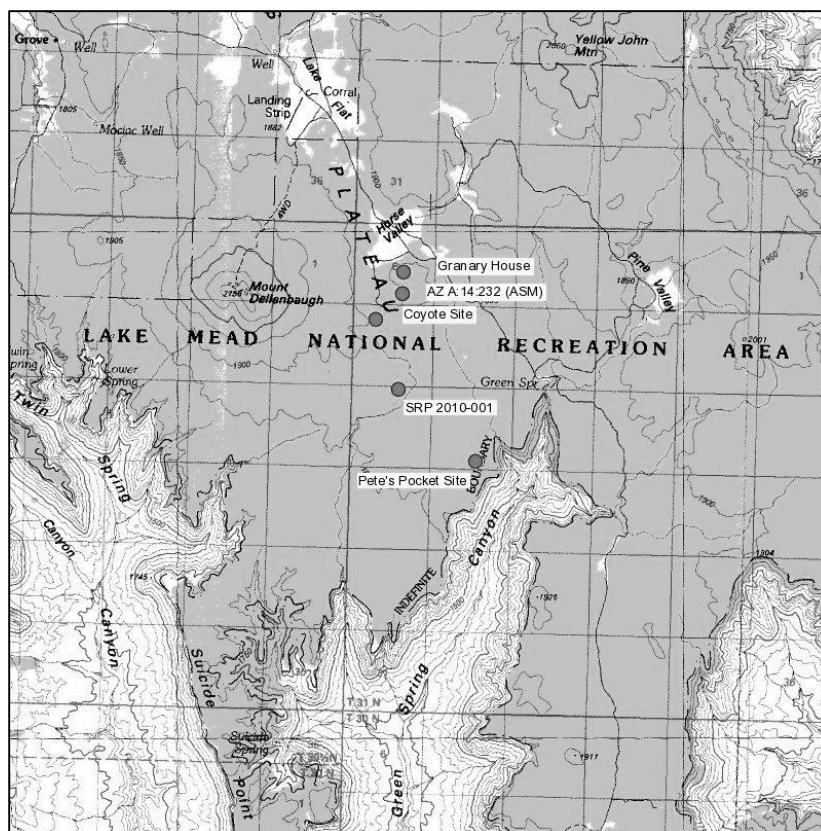


Figure 3.4: Site map of Granary House (AZ:A:14:46) (Harry n.d., Granary House)

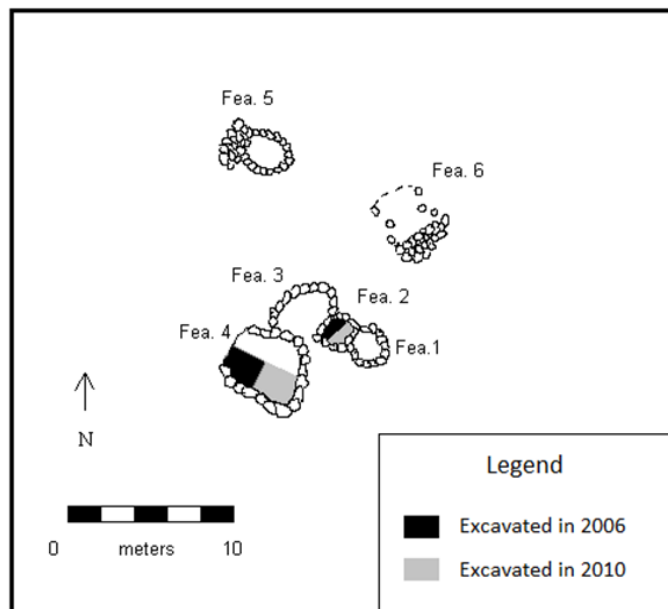
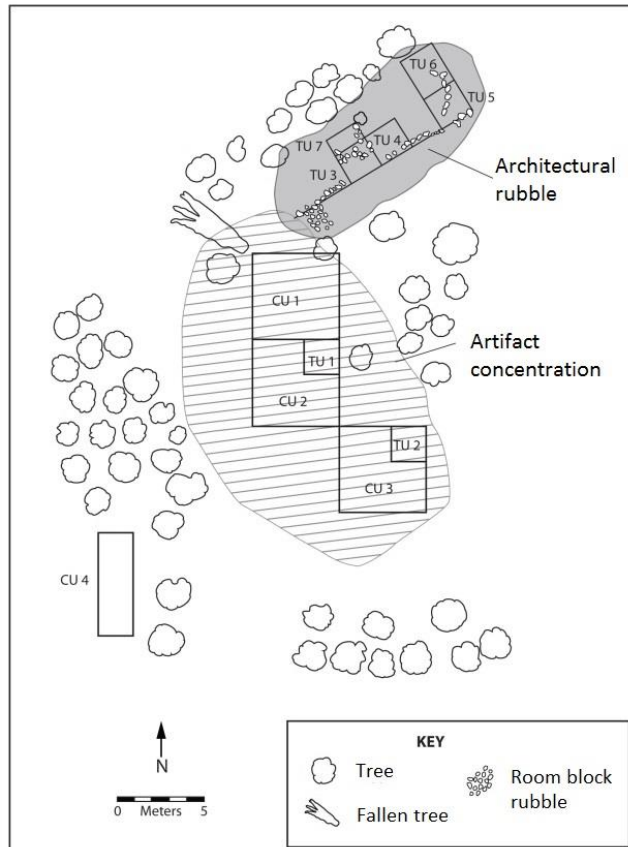


Figure 3.5: Site map of Site 232 (AZ:A:14:232) (Harry n.d.,



occupations. The first occupation dates to the Pueblo I or early Pueblo II period based on the low percentage of corrugated wares. The second occupation occurred during the late Pueblo II period due to the high percentage of corrugated wares and the presence of a Dogoszhi-style sherd. Except for a few juniper seeds, almost no wild plant remains were recovered. Unlike Granary House, most of the plant remains are from cultigens, specifically maize and squash. Pollen samples contained maize pollen, as well as cheno-am, juniper, and grasses. Karen Harry (n.d., Site 232) suggests Site 232 was a small farming hamlet because of the abundance of plant remains from cultigens, along with the large amount of ground stone present at the site.

All of the Shivwits Ware ceramics from the uplands are from Site 232, as many of the Shivwits Ware sherds at Granary House are atypical. Shivwits Ware ceramics generally have a brown paste and are tempered with crushed sherds. Many of the Shivwits Ware ceramics from Granary House have a brown paste, but they are tempered with olivine. AZ:A:232 was included in this study as the Shivwits Ware ceramics from this site are more representative of this particular ware.

Sample Preparation

I prepared all of the samples following the method outlined by Betenson (2005). A roughly 1x1 cm section of the sherd was cut using a Dremel tool. I avoided sampling any part of the sherd that had a label (usually created with a permanent marker and clear nail polish) in order to avoid contaminating the sample. Distilled water was sprayed on the sherd and blade during the cutting process to allow for easier cutting. After the sherd dried, I sanded each surface of the sherd down approximately 1mm using a Dremel 7700 rotary tool. I originally used an aluminum oxide grinding tool attachment, but discovered that the aluminum oxide attachment was not hard enough to easily burr away the surface of the sherd. Following Eerkens (2002), I switched to a

silicon carbide grinding attachment which made the process significantly easier. Grinding away the surface of the sherd helps reduce surface contamination (Eerkens 2000) As food residues are often absorbed into the sherds, this process does not grind away all of the residues.

I then coated the surface of the sherd with a small amount of analytical reagent grade methanol and allowed it to air dry. This process was performed under a fume hood to avoid inhalation of methanol vapors. Once the sherd was completely dry, I ground it into a fine powder using a porcelain mortar and pestle. The sherd powder was then transferred to a sterile cryovial for temporary storage until it could be analyzed.

Nitrile gloves were worn when handling sherds to prevent contamination from the oils in my fingertips. The cholesterol in fingerprints, in particular, can contaminate samples (Evershed 1993, Heron and Evershed:1993). All equipment, tools, and Dremel attachments were washed with soap and a stiff brush, then rinsed with distilled water after each use. Once the equipment dried, I coated it with a small amount of methanol and again allowed it to dry. Cleaning the equipment after each use helps reduce outside contamination, as well as cross-contamination.

Chapter 4: Results

In this chapter, I summarize the results of the residue analysis and discuss the methods I used to interpret the data. Gas chromatography and mass spectrometry (GC-MS) was used to separate and identify fatty acids present in organic residues present in the samples. The GC-MS was performed by Dr. Spencer Steinberg of the Department of Chemistry at the University of Nevada, Las Vegas. Approximately 25 to 35 mg of each sample were loaded into quartz tubes which had been pre-combusted at 1100°C. The sample was held in place with pre-combusted quartz wool, and then 20 uL (microliters) of 25% by weight tetramethylammonium hydroxide (in methanol) was added using a micropipette. The methanol was evaporated by heating the sample to 90°C for 30 seconds. The quartz tube was then ballistically heating to 800°C (600°C also tried) for 10 seconds causing simultaneous saponification and derivatization (to methyl esters). Samples were analyzed using a Varian Saturn 2200 GC/MS/MS with a CP-3800 gas chromatograph and CDS Analytical Pyroprobe 2000. Blanks were run in between samples to help prevent cross-contamination (Spencer Steinberg, personal communication, May 19, 2016).

Fatty acids are great targets for residue analysis because they are found in most plant and animal residues. They are made up of a carboxyl group (-COOH) and a chain of carbon and hydrogen atoms. Thanks to carbon's ability to form up to four bonds, fatty acids come in a variety of lengths and shapes. Saturated fatty acids, such as palmitic acid (C16:0), have no double bonds between carbon atoms in the tail of the fatty acid. Unsaturated fatty acids, like palmitoleic acid (16:1), have at least one double bond between carbon atoms. Figures 4.1 and 4.2 show examples of saturated and unsaturated fatty acids.

There are multiple notation systems for describing fatty acids which often refer to the number of carbon atoms, the number of double bonds, and the position of any double bonds. Some chemists and authors use common names (sometimes referred to as trivial nomenclature) to describe fatty acids. For example, *palmitic acid* (depicted in Figure 4.1) refers to a fatty acid with a 16-carbon chain. In this work, I will use a simple abbreviation system that demonstrates the number of carbon atoms in the chain and the number of double bonds. This naming convention is commonly used by chemists and archaeologists to describe the fatty acids and avoid confusion from common names, especially as some fatty acids have multiple names. Palmitic acid, for instance, is a saturated fatty acid (i.e. it contains no double bonds between carbon atoms) with 16 carbon atoms, so it will be referred to as C16:0. Palmitoleic acid (shown in Figure 4.2) contains a 16-carbon chain, but it also includes one double bond (making it a monounsaturated fatty acid); it will be referred to as C16:1.

Some chemists use delta or omega notation to further specify where the double bond is on the carbon chain for unsaturated fatty acids. The use of delta or omega depends on which end of the molecule you count from (Eerkens 2000:91). For example, palmitoleic acid could be written as either $\text{C16:1}\Delta 9$ (if you start counting from the carboxyl group, $-\text{COOH}$) or $\text{C16:1}\omega 7$ (if you start counting from the methyl end, $-\text{CH}_3$). I will not be using delta or omega notation in this work when referring to unsaturated fatty acids since it is not helpful for identifying the types of residues using my methods for interpreting the data.

Figure 4.1: Palmitic acid (C16:0), a saturated fatty acid

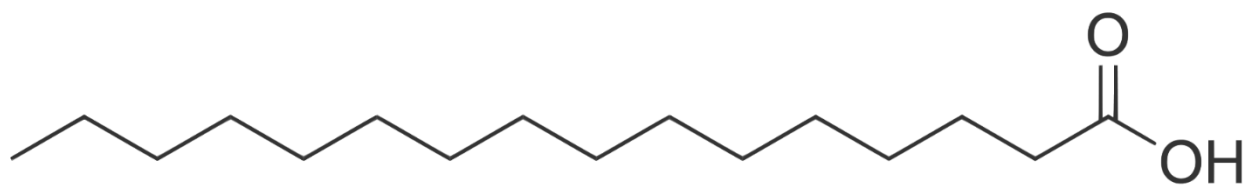
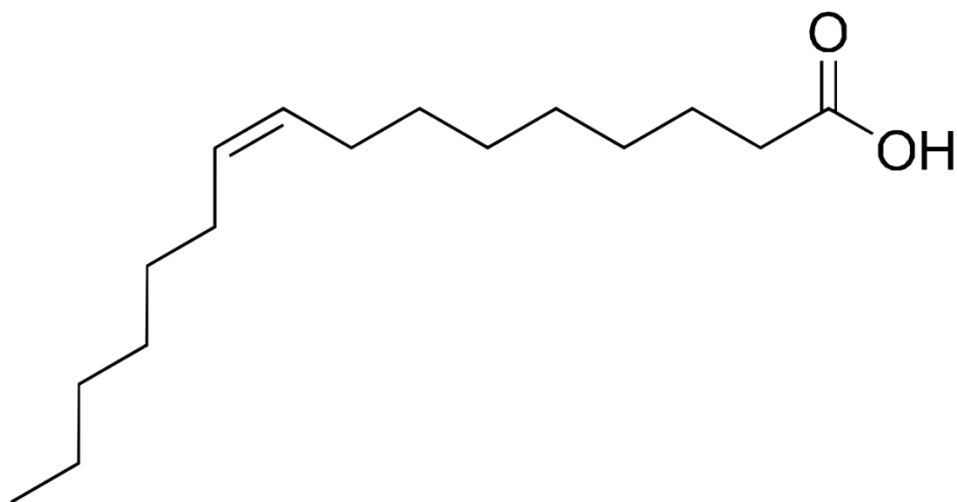


Figure 4.2: Palmitoleic acid (C16:1), an unsaturated fatty acid



Summary of Results

The GC-MS instrument was able to detect and identify fatty acids present in all of the samples. Most of the fatty acids present in the sample are medium chain or long chain fatty acids from C12:0 to C18:1. The majority of the fatty acids detected were saturated, but two monounsaturated fatty acids, specifically C16:1 and C18:1, were also present. Only two samples contained any polyunsaturated acids, both represented by the long-chain fatty acid C18:2. Blanks were run in between samples; however, the amount of background fatty acids in the blanks was extremely small, so the approximate integrated peak areas were used for this analysis. Table A.1 in the Appendix summarizes the fatty acids present in the samples and their approximate integrated peak areas.

Lipids are common targets for residue analysis because they are generally more resistant to decay and contamination from the surrounding soils, but they are not immune to these issues. Lignin, a polymer commonly found in plants, was present in one of the samples from the Shivwits Plateau. The presence of lignin indicates that chemicals from the soils in the depositional environment may have leached into the sample, possibly contaminating the sample. These chemicals could show up in the GC-MS results and lead to inaccurate interpretations of the possible origins of the residues. The results of the GC-MS did not return any evidence of cholesterol in the samples. An additional test, selective ion storage, was performed by the chemist, Dr. Spencer Steinberg, to look specifically for sterols in two of the samples, but none were detected. The presence of cholesterol in the samples would be an indicator of possible contamination from handling. The results of the GC-MS suggest that, except for the one sample containing lignin, contamination from the depositional environment and from handling during study is minimal.

Data Reduction and Analysis

Determining the origin of residues in archaeological contexts is difficult for several reasons. First, lipids (including fatty acids) are subject to degradation from exposure to heat. As Eerkens (2005:87) points out, the process of cooking, which often helps lipids become absorbed into the pores of ceramic vessels, can also cause them to break down: “Cooking exposes lipids to heat, which causes degradation. Of course, this is the goal of cooking in the first place; namely, to make foods easier to digest by breaking down complex compounds extrasomatically” (see also Malainey 1997). Any of the lipids present in the walls of ceramic cooking vessels were likely exposed to such heat degradation. Although fatty acids can withstand the temperatures involved with cooking (Skibo 1992), exposure to heat could still potentially affect the type and amount of fatty acids present in the samples, resulting in difficulty matching the lipid residues to the original food source.

Second, fatty acids degrade at different rates, with unsaturated fatty acids degrading faster than saturated fatty acids. Eerkens (2005:87) writes, “Unsaturated fats oxidize more quickly than saturated ones, the rate increasing over 10 times for each double bond present.” Malainey (1997) states that polyunsaturated fatty acids (i.e. fatty acids with multiple double bonds) are more vulnerable to autoxidation than saturated or monounsaturated ones. This process would affect the overall composition of the types of fatty acids found in the samples. For example, residues from archaeological contexts would probably contain lower relative percentages of polyunsaturated fatty acids compared to fresh, undegraded samples. This may explain the relative dearth of C18:2 in the samples.

Finally, lipids are found in a wide variety of plant and animal remains. In some cases, this can be helpful for identifying the sources of organic residues from archaeological contexts:

Different plants and animals produce different types and quantities of these compounds, providing the opportunity to ‘fingerprint’ different plants and animals according to their makeup of lipids. In fact, some lipid isomers are rare and only made by certain plant or animal species or families (referred to as biomarkers). In such a case the identification of this compound in an archaeological sherd provides strong evidence that that particular plant was cooked, processed, stored, served, or transported within the vessel. [Eerkens 2000:92]

For example, (Washburn et al. 2013) identified the presence of *Theobroma cacao* in ceramic vessels at Alkali Ridge in southeastern Utah based on the presence of theobromine, a biomarker for cacao. Likewise, Eerkens (2002) suggests that pinyon resins were occasionally prepared in ceramic vessels at the Nevada Test Site in western Nevada based on a high quantity of terpenes, including sesquiterpenoids and diterpenoids, present in one of the sherds.

Unfortunately, distinguishing the plant or animal that these residues may have come from is not always so straightforward. Many studies focusing on the identification of organic residues often use broad categories since many plants and animal contain similar types of fatty acids. As Eerkens (2002) points out, however, many of these fatty acids occur in different quantities. No biomarkers allowing for specific identification of any residues were found in the samples for this study. Therefore, I used two different types of analyses that focus on the relative quantities of fatty acids to identify the origins of the residues: (1) fatty acid ratios and (2) relative percentages of fatty acids.

(1) Fatty Acid Ratios

As mentioned earlier, fatty acids degrade at different rates – unsaturated fatty acids degrade at faster rates than saturated ones. This can result in different relative amounts of fatty acids in the samples compared to the amounts present in the source of the residues. One way to help control for this when interpreting the types of fatty acids present in archaeological residues is to look at ratios of fatty acids that degrade at similar rates. This type of analysis is based heavily on the work of Jelmer Eerkens (2001, 2002, 2005) who uses four ratios: (1) C16:1/C18:1, (2) C16:0/C18:0, (3) C12:0/C14:0, and (4) (C15:0 + C17:0)/C18:0. The values for the calculated ratios for the samples in this research are listed in Table A.2 in the Appendix.

Once the values for the four ratios were calculated using the integrated peak areas, those values were used to determine possible sources for the residues. This technique is able to narrow

Table 4.1: Criteria used to distinguish food types based on fatty acid ratios (Eerkens 2005:91)

Ratio	State	Terrestrial mammals	Fish	Roots	Greens	Seeds and nuts	Berries
<u>(C15:0+C17:0)</u>	Fresh	<0.2	0.2-0.5	>0.2	0.1-1.0	<0.6	<0.2
C18:0	Degraded	<0.2	0.2-0.5	>0.2	0.1-1.0	<0.6	<0.2
<u>C16:1</u>	Fresh	0.02-0.2	0.2-0.5	0.05-0.7	>0.7	<0.3	<0.08
C18:1	Degraded	0.08-0.8	0.8-2.0	0.2-2.8	>2.8	<1.2	<0.32
<u>C16:0</u>	Fresh	<3.5	4-6	3-12	5-12	0-9	2-6
C18:0	Degraded	<7	8-12	6-24	10-24	0-18	4-12
<u>C12:0</u>	Fresh	<0.15	<0.15	>0.15	>0.05	>0.15	>0.15
C14:0	Degraded	<0.15	<0.15	>0.15	>0.05	>0.15	>0.15

down residues into six broad categories: seeds/nuts, roots, berries, greens, fish, and mammal². I compared the values for my samples to Eerkens's criteria in his 2005 publication, "GC-MS Analysis and Fatty Acid Ratios of Archaeological Potsherds from the Western Grate Basin of North America." As these samples come from archaeological contexts and date to ca. A.D. 1050-1150, I used the degraded values from Eerkens' publication for this analysis.

Different ratios give better resolution on different categories of food residues. For example, degraded residues from fish have higher levels of C16:0/C18:0, while residues from terrestrial mammals have very low values. Given the overlap between many of these categories, the samples sometimes meet the criteria for two or more categories. A value of 10 for C16:0/C18:0, for instance, would fall into the degraded categories for fish, roots, greens, seeds/nuts, and berries. The values for each of the four ratios were used to create scatterplots in SPSS and then the ellipses were added using the criteria in Table 4.1 to help narrow down and visualize which categories of foods the residues may have come from. The samples were plotted both by ware (i.e. Moapa Gray Ware, Shivwits Ware, and Tusayan Virgin Series) and location (i.e. Shivwits Plateau vs. Moapa Valley).

As shown in the scatterplots (Figures 4.3-4.6), there is often overlap between the six categories, with the values for many samples falling into two categories. One sample does not fit into any of the categories based on its values for $(C15:0 + C17:0)/C18:0$ and $C16:1/C18:1$. For the first two ratios, $(C15:0 + C17:0)/C18:0$ and $C16:1/C18:1$, the samples fall mainly in the roots

² Berries are considered a subgroup of seeds/nuts (Jelmer Eerkens, personal communication, April 21, 2016).

Figure 4.3: Scatterplot of $(C15:0 + C17:0)/C18:0$ and $C16:1/C18:1$ by ware

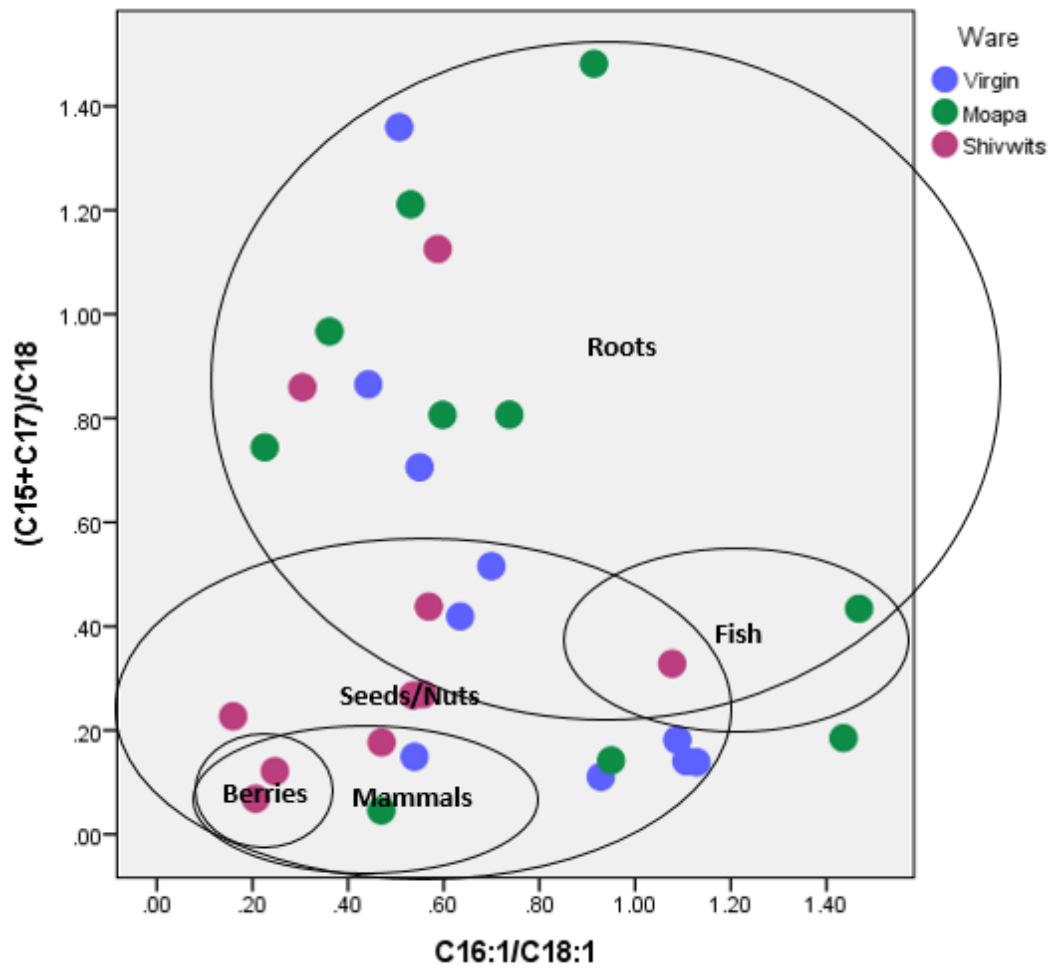
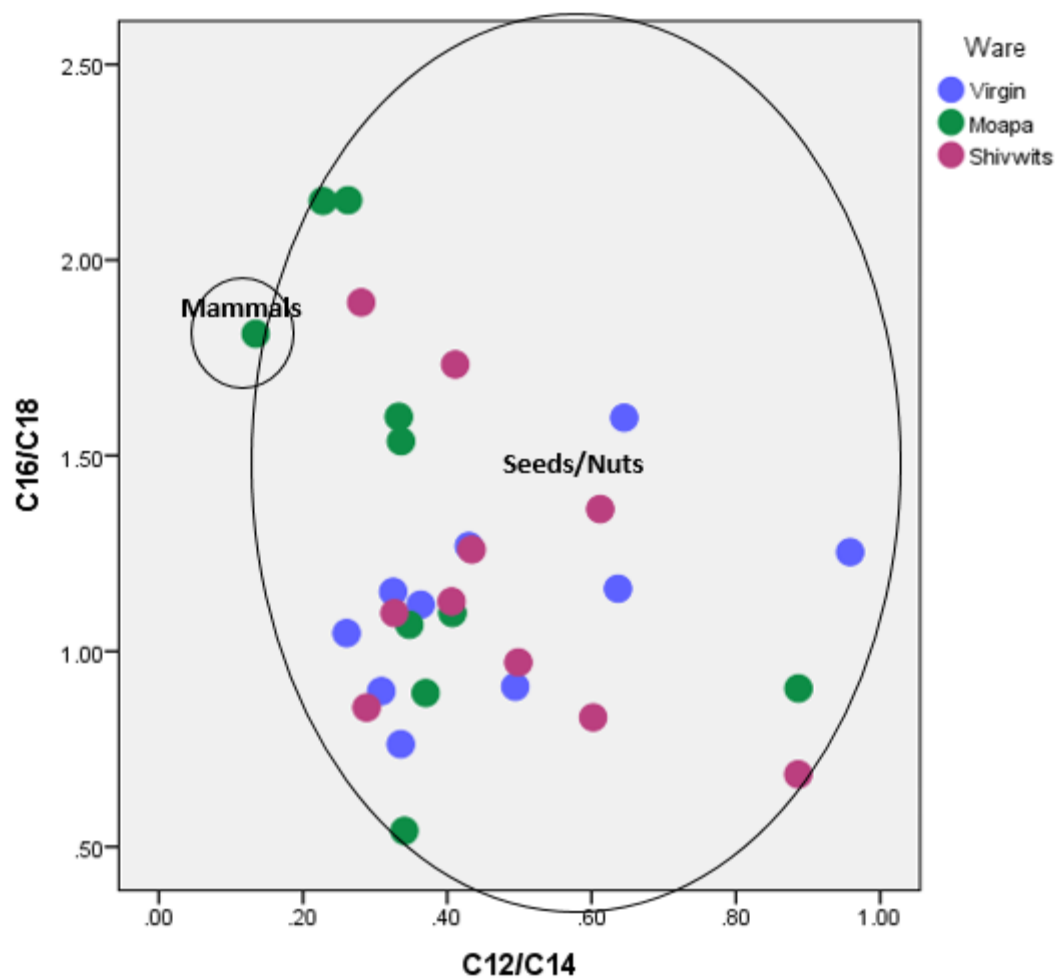


Figure 4.4: Scatterplot of C16:0/C18:0 and C12:0/C14:0 by ware



category and the seeds and nuts category. For the second two ratios, C16:0/C18:0 and C12:0/C14:0, the samples fall predominately in the category for seeds/nuts. Examples of seeds and nuts include maize, pinyon nuts, chia seeds, amaranth seeds, and mesquite seed pods. Examples of foods in the roots category include agave roots and desert lily bulbs. Desert lily bulbs have roughly the same nutritional value as a potato and are found on Mormon Mesa, located between the Muddy River and the Virgin River (Daron Duke, personal communication, March 16, 2016). Two samples had values for (C15:0 + C17:0)/C18:0 and C16:1/C18:1 that fall into the category for fish; however, their values for C12:0/C14:0 and C16:0/C18:0 do not meet the criteria for fish, suggesting the residues from those samples likely came from roots or seeds/nuts instead. None of the fatty acid ratio values resemble the residues from greens, and very few samples fall into the mammals category. Some samples fall into the categories for both mammals and seeds/nuts for (C15:0 + C17:0)/C18:0 and C16:1/C18:1, and only one is included in the mammals category for (C15:0 + C17:0)/C18:0 and C16:1/C18:1. Based on these results, the residues most likely originated from a source resembling seeds/nuts or roots.

As demonstrated by Anderson (2011), the temper used to make ceramic vessels can affect their performance characteristics. Specifically, Tusayan Virgin Series ceramics were more susceptible to fissures and cracks than Moapa Gray Ware and Shivwits Ware ceramics due to their sand temper. Differences in the wares' performance characteristics could possibly affect how they were used. The values for the four fatty acid ratios were plotted by ware (Figures 4.3 and 4.4) to see if there were any differences in how the wares were used. All three wares contained similar values for the four fatty acid ratios. Since I have a small sample size, a Kruskal-Wallis rank sum test was used to confirm that there were no significant differences in

the ratio values based on ware³. It appears all three wares contained a variety of residues and were not used exclusively for certain categories of food.

Since there are different types of wild plant and animal resources available in the Moapa Valley and on the Shivwits Plateau, as well as different conditions for maize agriculture, I plotted the values for the four fatty acids based on location (shown in Figures 4.5 and 4.6) to see if there were differences in the types of residues found in ceramics from upland and lowland VBP sites. The plot for the ratios C12:0/C14:0 and C16:1/C18:1 (Figure 4.6) shows no discernable groupings for the residues based on location; however, there is a pattern present for (C15:0 + C17:0)/C18:0 as shown in Figure 4.5. Specifically, values for the Shivwits Plateau are lower than those for the Moapa Valley, with more samples from the uplands falling into the seeds/nuts and mammals category rather than the roots category. A Mann-Whitney U test was used to test if the two groups are significantly different. The test returned a p-value of 2.514e-06 for (C15:0 + C17:0)/C18:0, suggesting there is a difference between the residues from upland and lowland sites for this ratio. There was no significant difference for the other three ratios.

Because only one ratio, (C15:0 + C17:0)/C18:0 was showing groupings based on location, I also tested to see if there were differences in the relative percentages of the integrated peak areas for the individual fatty acids in that ratio. A Mann-Whitney U test showed no significant differences for the relative percentages of the integrated peak areas for C18:0 (p-value = .206) and C15:0 (p-value = .237) between the Moapa Valley and the Shivwits Plateau. There were significant difference between the two areas for the C17:0 (p-value = .029), and this may be what is driving the difference for the whole ratio. Eerkens (2005:96) writes that ruminant animal

³ The Kruskal-Wallis rank sum test returned the following p-values: (C15:0 + C17:0)/C18:0 p-value = 0.3934, C16:1/C18:1 p-value = 0.09107, C12:0/C14:0 p-value = 0.2795, and C16:0/C18:0 p-value = 0.6871.

Figure 4.5: Scatterplot of $(C15:0 + C17:0)/C18:0$ and $C16:1/C18:1$ by location

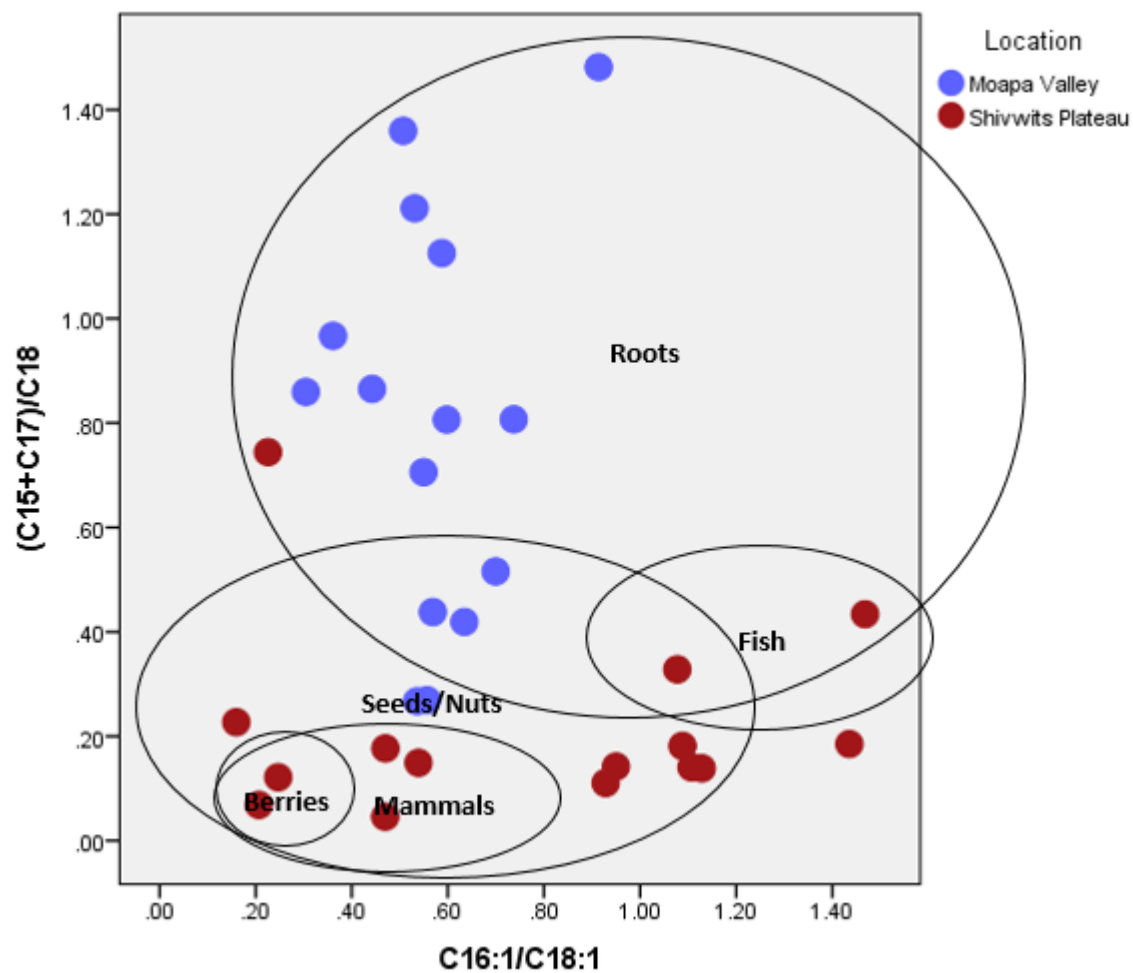
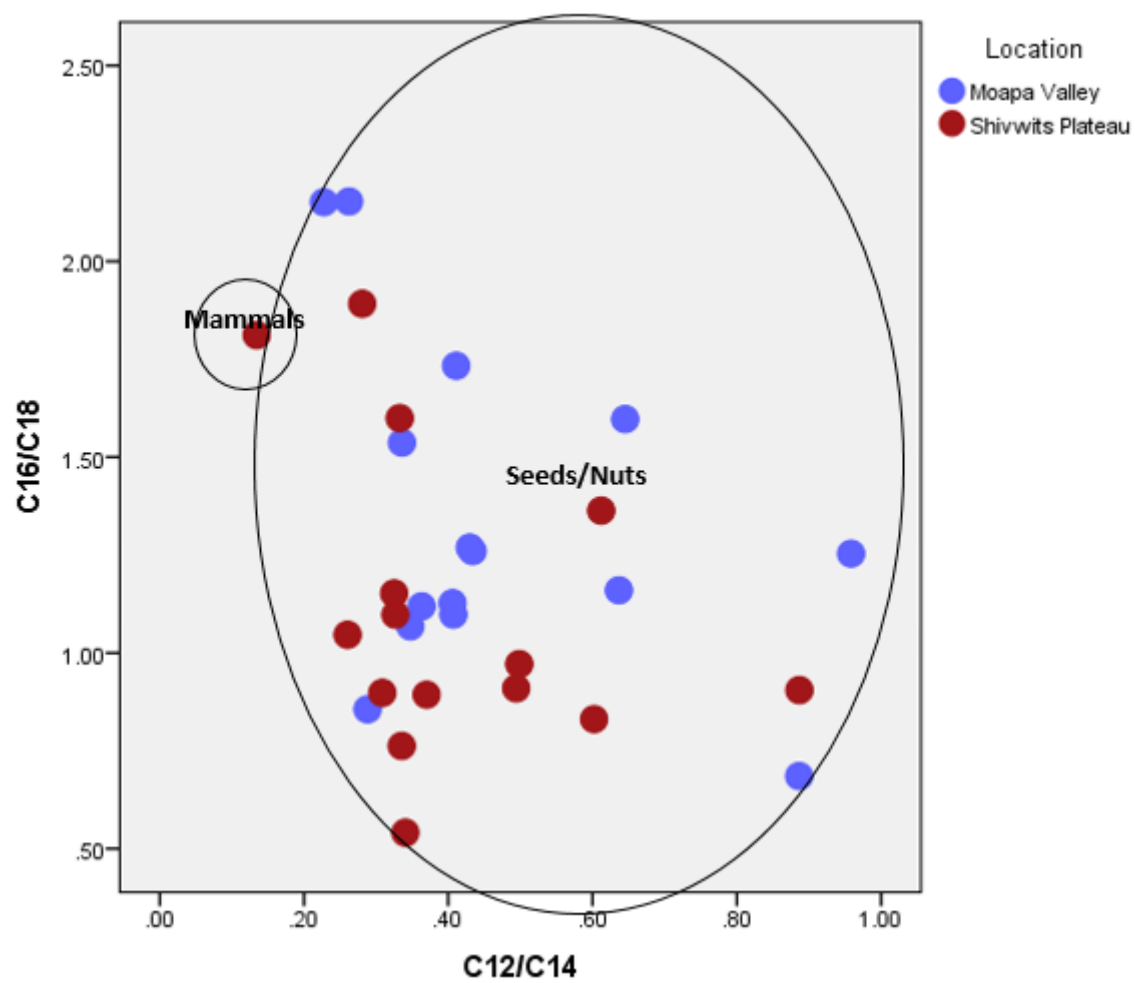


Figure 4.6: Scatterplot of C16:0/C18:0 and C12:0/C14:0 by location



meat often contain high quantities of C15:0, C17:0, and other fatty acids with an odd number of carbon atoms in the chain, but this does not fit with the data from using the ratios C12:0/C14:0 and C16:0/C18:0 which suggests the residues come from roots. Additionally, the relative percentages of C17:0 were lower on the Shivwits Plateau (where large mammals are more abundant) than in the Moapa Valley. Overall, only one ratio displays any significant differences in the types of residues present in the samples based on location, while three out of the four ratios show no difference in the types residues.

(2) Relative percentages of fatty acids

Another method for interpreting the results of GC-MS relies on the relative percentages of specific fatty acids or groups of fatty acids. This method is based on the work of Mary Malainey (see Malainey 1997, Malainey et al. 1999, Malainey 2008). By comparing known samples of foods to their residues, Malainey et al. (1999) created a set of criteria which could be used to determine the possible origins of residues found in archaeological contexts. Food samples were boiled in ceramic vessels, and then the pot was broken to create two sets of sherds. One set of sherds was placed in the freezer, while the other set was placed in an oven heated to 75°C to mimic degradation over time. Malainey et al. then used principal component analysis (PCA) to characterize the types of residues present in the experimental samples. Based on this information, they created criteria for identifying seven categories of residues: large herbivore, large herbivore with plant *or* bone marrow, plant with large herbivore, beaver, fish or corn, fish or corn with plant, and plant (except corn). The categories are based on the relative percentages of C18:0, C18:1, and medium chain fatty acids (C12:0, C14:0, and C15:0) as shown in Table 4.2.

Table 4.2: Relative percentages of fatty acids used to identify archaeological residues (Malainey et al. 1999:100)

Identification	Medium Chain	C18:0	C18:1 isomers
Large herbivore	$\leq 15\%$	$\geq 27.5\%$	$\leq 15\%$
Large herbivore with plant or bone marrow	Low	$\geq 25\%$	$15\% \leq X \leq 25\%$
Plant with large herbivore	$\geq 15\%$	$\geq 25\%$	No data
Beaver	Low	Low	$\geq 25\%$
Fish or corn	Low	$\leq 25\%$	$15\% \leq X \leq 27.5\%$
Fish or corn with plant	$\geq 15\%$	$\leq 25\%$	$15\% \leq X \leq 27.5\%$
Plant (except corn)	$\geq 10\%$	$\leq 27.5\%$	$\leq 15\%$

Relative percentages were calculated using the approximate integrated area peaks listed in Table A.1 in the Appendix. For categories marked as “Low,” I included any values less than 10%. I omitted the category for beaver from this analysis as beavers are not naturally found in southern Nevada or northern Arizona. The relative percentages for medium chain fatty acids, C18:0, and C18:1 isomers in my samples were compared against the values in Table 4.2 to determine the likely origins of the residues. The calculated relative percentages can be found in Table A.3 in the Appendix, and the identification of the sample residues are presented in Table 4.3. In some cases, the relative percentages for the samples did not meet the criteria for any type of residues, so those samples have been marked “N/A” under the “Identification” column.

Out of all 30 samples, 11 samples (37%) had residues resembling those from large herbivores, 7 samples (23%) resembled residues from plants (except corn), 2 samples (7%) resembled residues from plants with large herbivores, and 3 samples (10%) resembled residues from large herbivores with plants. Interestingly, only one sample (0.03%) had residues resembling fish or corn with plants, and none of the residues resembled the category for fish or corn. While archaeologists disagree about exactly how dependent VBP groups were on maize

Table 4.3: Identification of sample residues based on relative percentages

Catalog #	Ware	Location	Identification
A103-69 (A)	TV	Moapa Valley	N/A
A103-7 (A)	TV	Moapa Valley	Plant (except corn)
A103-7 (B)	TV	Moapa Valley	Plant (except corn)
A103-37	TV	Moapa Valley	Large herbivore
A103-69 (B)	TV	Moapa Valley	Plant with large herbivore
A103-58	MGW	Moapa Valley	Plant (except corn)
A103-17	MGW	Moapa Valley	N/A
A103-89	MGW	Moapa Valley	N/A
A105-1	MGW	Moapa Valley	Large herbivore w/ plant or bone marrow
A105-29	MGW	Moapa Valley	Plant (except corn)
A105-42	SV	Moapa Valley	Large herbivore
A105-46 (A)	SV	Moapa Valley	Large herbivore
A105-54	SV	Moapa Valley	Fish or corn w/ plant
A105-33	SV	Moapa Valley	Plant (except corn)
A105-46 (B)	SV	Moapa Valley	Plant with large herbivore
LAKE 20334	TV	Shivwits Plateau	Large herbivore
LAKE 303707	TV	Shivwits Plateau	Large herbivore
LAKE 307076	TV	Shivwits Plateau	Large herbivore
LAKE 30707	TV	Shivwits Plateau	Large herbivore
LAKE 20321	TV	Shivwits Plateau	Large herbivore
LAKE 20334 (A)	MGW	Shivwits Plateau	Large herbivore
LAKE 20334 (B)	MGW	Shivwits Plateau	Large herbivore w/ plant or bone marrow
LAKE 20362	MGW	Shivwits Plateau	Large herbivore
LAKE 20335	MGW	Shivwits Plateau	Large herbivore
LAKE 30708	MGW	Shivwits Plateau	Plant (except corn)
LAKE 20897	SV	Shivwits Plateau	N/A
LAKE 20923A	SV	Shivwits Plateau	N/A
LAKE 20890B	SV	Shivwits Plateau	Plant (except corn)
LAKE 20923B	SV	Shivwits Plateau	Large herbivore w/ plant or bone marrow
LAKE 20890A	SV	Shivwits Plateau	N/A

agriculture, most agree that it was an important part of their diet and subsistence strategies, so the absence of residues from maize in both areas is surprising. Six samples did not meet the criteria for any categories.

There do not appear to be any differences in the types of foods cooked, prepared, or stored in the ceramic vessels based on ware. A Kruskal-Wallis rank sum test was used to compare the relative percentages of fatty acids between the three wares (Moapa Gray Ware, Shivwits Ware, and Tusayan Virgin Series). Looking at the relative percentages of C18:0, C18:1 isomers, and medium chain fatty acids, the Kruskal-Wallis rank sum test returned p-values of 0.3229, 0.3422, and 0.9219 respectively. There are some differences, however, concerning how the pots were used between the two methods. Using the ratios of fatty acids to identify the residues, it appears all three wares were used to cook, prepare, or store mostly seeds, nuts, and roots. Using the relative percentages of fatty acids to identify the residues shows that the wares were likely used to prepare a wider variety of foods, from large herbivores to plants.

Out of the 15 samples from the Shivwits Plateau, 10 (67%) of the samples contained residues that resemble those from large herbivores (i.e. they meet the criteria for large herbivores, large herbivores with plant *or* bone marrow, or plants with large herbivore), while 6 (40%) of the samples in the Moapa Valley contained residues from large herbivores. People living on the Shivwits Plateau would have had easy access to large mammals such as mule deer, so this is not surprising.

What is surprising about these results is that they do not match the results using the ratios of fatty acids. Using the ratio of fatty acids, it appears the residues came from seeds/nuts and roots with very few values matching the criteria for residues from mammals. This method, on the

other hand, suggests many of the residues came from large herbivores or a mixture of large herbivores and plants. No sterols, which would also provide evidence for either plant or animal residues, were found in the samples using GC-MS and selective ion storage. Both methods attempt to account for the degraded nature of the fatty acids from archaeological contexts – the ratio method compares fatty acids that degrade at similar rates, while the relative percentage method is based on the values for experimentally degraded residues (rather than fresh ones). However, each method relies on different ratios of fatty acids, thus placing slightly more emphasis on certain fatty acids over others which could lead to different interpretations. It is also possible that the different methods pick up different residues better, so these results may not be mutually exclusive. More research is needed to determine the advantages and limitations of each method.

Research Limitations

There are a few issues which limit the use of GC-MS for interpreting residues from archaeological contexts: (1) contamination, (2) decay, (3) inability to detect mixtures, and (4) inability to detect residues from multiple uses.

As previously mentioned, lipids are relatively resistant to contamination from soils in the burial environment compared to other types of organic molecules. They are not, however, immune to contamination. Contamination from the burial environment is possible, and one sample did contain lignin which signals that it and other chemicals may have leached into the ceramics from the surrounding soils. I took several steps to avoid contamination during preparation for GC-MS analysis such as wearing latex gloves when handling the sherds, using distilled water when preparing the sherds, and burring away the outer 1mm of the sherd using a

Dremel tool. I also took steps to avoid cross-contamination between the samples by cleaning all equipment between use. However, some contamination from when the sherd entered the archaeological context to when it was prepared is still possible.

Second, degradation is one of the biggest issues when dealing with organic residues in archaeological contexts. It can cause issues when attempting to match archaeological residues to fresh, modern-day plant and animal residues. For example, unsaturated fatty acids, especially those with multiple double bonds, degrade more quickly than saturated fatty acids. The relative amounts of fatty acids in the degraded residues can thus be very different from the amounts in fresh samples. This could affect the relative percentages of the different fatty acids which would in turn affect the interpretation. Using the ratio of fatty acids helps minimize this issue by analyzing ratios of fatty acids which decay at similar rates. Using degraded residues from known foods, rather than fresh samples, to create criteria for identifying archaeological residues can also help reduce this factor.

Third, it is difficult to detect mixtures using GC-MS. This process separates the chemical compounds present in the residues and then identifies them based on their mass. Fatty acids are found in almost all plant and animal residues, and many residues contain the same types of fatty acids, just in different quantities. For example, residues from large herbivores contain higher relative amounts of C18:0 than residues from fish or corn (Malainey et al. 1999). If there are residues from multiple sources – such as a stew with nuts, maize, and meat –it is difficult to pick out the individual components without biomarkers specific to certain plants or animals.

Finally, GC-MS cannot identify residues from multiple uses. As mentioned in previous chapter, the residues absorbed into ceramic vessels are believed to be from the first few uses as

the pores in the ceramic vessels become plugged after the first few uses and cannot absorb more residues. If the vessel served multiple functions or was later used for a different purpose, the residues may not be representative of everything that was cooked, prepared, or stored inside the vessel. Additionally, seasonality could affect the type of food residues present in the ceramics as some foods are not available year-round. GC-MS, however, does provide a good snapshot of some of the foods people were preparing in ceramic vessels, and sampling a variety of wares and sites would help archaeologists gain a better understanding of the scope of foods people were using.

Chapter 5: Conclusions

For this research, I analyzed organic food residues in three types of undecorated ceramic wares (Moapa Gray Ware, Shivwits Ware, Tusayan Virgin Series) from Virgin Branch Puebloan sites in northern Arizona and southern Nevada dating to the Middle PII period. GC-MS was used to separate and identify lipids, specifically fatty acids, in the residues to identify possible their sources. These data were used to look at potential differences in the types of residues found at upland sites on the Shivwits Plateau and lowland sites in the Moapa Valley, as well as possible difference in how the three types of ceramic wares were used. In this chapter, I revisit my research questions and discuss future directions for archaeological research using residue analysis.

Research Questions Revisited

1. What do the residues suggest about the VBP diet and subsistence strategies?

I used two different methods to identify possible sources of the residues present in my samples, and the answer to this questions depends on the method. The first method I used identified possible sources for the residues based on the values of four ratios of fatty acids (see Eerkens 2005). The values for these ratios suggest that these ceramic vessels were used to cook, prepare, or store predominately seeds, nuts, and roots. These types of residues could come from maize or wild foods such as amaranth seeds, pinyon nuts, or desert lily bulbs. Further analysis using stable carbon isotope analysis would be useful for identifying plants in the residues (based on their photosynthesis pathways) and specifically identifying the presence of maize in the residues. Finding evidence of maize in most of the residues would suggest VBP groups did indeed rely heavily on maize agriculture, while finding high quantities of agave, tubers, or other

wild foods would suggest that wild foods played an important role in their diet and subsistence strategies.

The second method I used to identify possible sources of the residues relied on the relative percentages of specific fatty acids (see Malainey et al. 1999). The results from this method indicate many of the ceramic vessels were used to cook, store, or prepare large herbivore meat or a mixture of large herbivore meat and plants. The most likely sources for these residues would be bighorn sheep and mule deer. Some of the samples contained residues fitting the criteria for plants (except corn), and only one sample contained residues matching the criteria for fish or corn. This does not mean VBP groups were not consuming maize, but it does suggest that wild resources, especially large game, were an important part of their diet and subsistence strategies. Interestingly, both methods showed little evidence of residues from fish, suggesting that fish were not eaten or were perhaps prepared in another manner (such as roasting or smoking).

2. Are there differences in the types of foods found at upland sites compared to lowland sites?

The results for both methods showed little differences in the types of residues between upland and lowland sites. Analyzing the results of the GC-MS using four ratios of different fatty acids showed that most of the residues from both the Shivwits Plateau and the Moapa Valley likely came from seeds, nuts, or roots. Only one ratio, $(C15:0 + C17:0)/C18:0$, was significantly different between upland and lowland site. Analyzing the results using the relative percentages of fatty acids returned different results; most of the samples from both areas contained residues resembling those from large herbivores, large herbivores with plants (or bone marrow), plants with large herbivores, and plants (except corn).

While the two methods indicated different types of residues were present in the ceramics, they both showed little differences in the types of residues present based on location. This is interesting given that the environment, climatic conditions, and wild resources are different in each area. It suggests VBP groups in both the lowland and upland areas were relying on similar resources. Large herbivores are not as common to the Moapa Valley, but VBP groups living in this area could have gained access to bighorn sheep at Valley of Fire or mule deer (in the Virgin Mountains) via direct procurement, exchange, or seasonal gatherings. Larger sample sizes and samples from more sites in both areas are needed to determine whether or not there are differences in the types of foods prepared in ceramic vessels from these two areas.

3. Were ceramic vessels in the VBP area used differentially based on ware?

Moapa Gray Ware, Shivwits Ware, and Tusayan Virgin Series ceramics do not appear to have been used differently based on ware. These three wares were all part of a ceramic distribution network between upland and lowland VBP sites (Harry et al. 2013). Moapa Gray Ware and Shivwits Ware ceramics produced in the uplands are found in relatively large quantities in the lowlands, while Tusayan Virgin Series ceramics made in the lowlands are found at upland sites. Identifying the residues based on fatty acid ratios showed that all three wares were probably used to prepare seeds, nuts, and roots. Analyzing the relative percentages of fatty acids in the residues showed more variety in the types of foods which may have been prepared in the original vessels – large herbivore, plants (except corn), large herbivore with plants (or bone marrow), and plants with large herbivore. However, there were also no discernable groupings based on ware using this method, suggesting the wares were not used to cook different types of foods based on their performance characteristics or an association between the ceramic's production zone and foods specific to that zone.

Future Research

This study has identified broad categories of foods present in VBP ceramics from southern Nevada and northern Arizona; however, more research is needed to sufficiently narrow down the sources of these residues. In this section, I discuss several possible directions for future research. First, additional tests can be run on the same samples used in this research as no sherds were completely destroyed and all prepared samples have been saved. For example, stable carbon and nitrogen isotope analysis could be run on these samples to look for specific types of plant residues. This technique can be used to identify residues from plants based on their photosynthetic pathways. Most plants are C₃ plants, but maize is a C₄ plant which allows it to be identified using this technique (see Chisholm and Matson 1994 and Martin 1999 for examples using skeletal remains).

Another direction for future research is to look at changes in residues over time. All of the sites included in this study date to the Middle PII period (ca. A.D. 1050-1150). As I wanted to look at possible differences in the types of residues based on location and ware, I picked sites all dating to the same time period to avoid having any differences in the types of residues showing up as a result of differences in diet and subsistence strategies throughout time. Some archaeologists (e.g. Martin 1999 and McFadden 1996) have argued that VBP groups were dependent on maize agriculture at an early date, while other researchers write that VBP groups became more dependent on maize over time (e.g. Larson and Michaelsen 1990 and Larson 1996). One possible study would be to sample sites from multiple times periods and investigate if the residues changed over time and, if so, how they changed.

Finally, more research is needed regarding how to identify the possible sources of organic residues using GC-MS. I used two different methods for interpreting the data on the same

samples and identified different possible sources depending upon which method I used. It is possible that these results are not mutually exclusive, as each method may be better at picking up different types of residues, and experimental archaeology would be a useful approach for this issue. One possible research project would be to prepare several types of foods in ceramic vessels, then simulate degradation over time by exposing them to heat. The results of the GC-MS analysis could be interpreted using both the ratios of fatty acids and relative percentages to test both analysis methods on known residues. Understanding how fatty acids in archaeological contexts relate to the original sources is complicated due to degradation, but this type of research would be extremely helpful for determining the advantages and limitations of the two analysis methods.

Significance

Currently, there is very little research on Virgin Branch Puebloan diet and subsistence strategies, especially on the Shivwits Plateau, but this study has helped identify possible sources of organic residues cooked, prepared, and stored in VBP ceramic vessels. This project is one of few studies to perform on samples from the Moapa Valley (Harry et al. 2008 being the other example), and the only published study on residue analysis in the upland VBP area. Furthermore, this is the only known study to analyze the results using the ratios of fatty acids and the relative percentages. This study demonstrated that GC-MS is a promising method for identifying the types of foods prehistoric groups cooked, prepared, and stored in VBP ceramics; however, the contradictory results of this research highlight the need for further research in residue analysis and how to identify the sources of archaeological residues, an important step for future research.

Appendix: Analysis Tables

Table A.1: Integrated peak areas for most common fatty acids present in samples

Catalog #	Ware	Location	C12:0	C14:0	C15:0	C16:1	C16:0	C17:0	C18:1	C18:0
A103-58	MGW	MRS 73-34	95362	283857	172115	345333	1220000	158329	468460	793889
A103-17	MGW	MRS 73-34	79254	301878	175631	666500	1315000	185561	729372	610789
A103-89	MGW	MRS 73-34	117547	288665	209877	606546	1668000	266766	1015000	1519000
A105-1	MGW	MRS 73-5	67291	193661	141857	345471	1213000	174761	956634	1136000
A105-29	MGW	MRS 73-5	93887	412586	189298	287068	1296000	191258	540572	602552
A105-42	SV	MRS 73-5	230542	260077	138321	309158	1766000	197728	555480	2577000
A105-46(A)	SV	MRS 73-5	60178	208834	104797	169080	1346000	130383	315373	1572000
A105-54	SV	MRS 73-5	150706	347311	126789	197110	1135000	308992	647468	900801
A105-33	SV	MRS 73-5	263332	640671	254709	405756	1456000	337419	690627	840014
A105-46(B)	SV	MRS 73-5	296667	730772	432634	254200	2263000	368152	446803	2008000
A103-69(A)	TV	MRS 73-5	116461	180497	129938	427626	1143000	138938	843303	715800
A103-7(A)	TV	MRS 73-34	182658	190587	194523	223793	1015000	265139	505957	809763
A103-7(B)	TV	MRS 73-34	151135	237382	190187	314793	1254000	265083	572798	1081000
A103-37	TV	MRS 73-34	64236	176860	102164	218311	1192000	134357	344082	1065000
A103-69(B)	TV	MRS 73-34	127703	297101	181344	241787	1297000	154056	345673	1022000
LAKE 30708	MGW	AZ:A:14:46	23843	177531	70310	130120	652222	85931	88620	360061
LAKE 20334A	MGW	AZ:A:14:46	110080	323174	134016	252682	3910000	197121	538094	7226000
LAKE 20334B	MGW	AZ:A:14:46	248336	280023	166124	385652	1817000	132800	1709000	2008000
LAKE 20362	MGW	AZ:A:14:46	30524	91714	20747	34561	490393	36046	24076	306614

LAKE 20335	MGW	AZ:A:14:46	161544	436589	191057	460707	2002000	127580	484957	2241000
LAKE 20890B	SV	AZ:A:14:232	66501	236953	88622	162382	917680	70514	150685	485090
LAKE 20923B	SV	AZ:A:14:232	136957	227420	78185	279440	2031000	89158	1352000	2444000
LAKE 20897	SV	AZ:A:14:232	109462	334987	144747	655129	1619000	115870	1394000	1475000
LAKE 20923A	SV	AZ:A:14:232	183021	299042	165382	976066	1974000	163377	6115000	1448000
LAKE 20890A	SV	AZ:A:14:232	178428	357913	158639	729137	2383000	139444	2954000	2453000
LAKE 20334	TV	AZ:A:14:46	37648	144600	55945	57357	705691	37518	50823	674435
LAKE 20321	TV	AZ:A:14:46	168120	501151	232759	458588	2783000	170434	493927	3650000
LAKE 307076	TV	AZ:A:14:46	131825	427233	178305	359520	2043000	141840	324791	2275000
LAKE 30707	TV	AZ:A:14:46	69632	214284	127823	424181	1332000	81938	389751	1156000
LAKE 303707	TV	AZ:A:14:46	68186	137955	110606	217709	1117000	72573	403969	1228000

Table A.2: Calculated values for fatty acid ratios

Catalog #	Ware	Location	$\frac{(C15:0 + C17:0)}{C18:0}$	$\frac{C16:1}{C18:1}$	$\frac{C16:0}{C18:0}$	$\frac{C12:0}{C14:0}$
A103-58	MGW	MRS 73-34	0.8069	0.7372	1.5367	0.3360
A103-17	MGW	MRS 73-34	1.4817	0.9138	2.1530	0.2625
A103-89	MGW	MRS 73-34	0.8064	0.5976	1.0981	0.4072
A105-1	MGW	MRS 73-105	0.9670	0.3611	1.0678	0.3475
A105-29	MGW	MRS 73-105	1.2113	0.5310	2.1509	0.2276
A105-42	SV	MRS 73-105	0.2692	0.5566	0.6853	0.8864
A105-46(A)	SV	MRS 73-105	0.2673	0.5361	0.8562	0.2882
A105-54	SV	MRS 73-105	0.8595	0.3044	1.2600	0.4339
A105-33	SV	MRS 73-105	1.1254	0.5875	1.7333	0.4110
A105-46(B)	SV	MRS 73-105	0.4380	0.5689	1.1270	0.4060
A103-69(A)	TV	MRS 73-34	1.3597	0.5071	1.5968	0.6452
A103-7(A)	TV	MRS 73-34	0.8650	0.4423	1.2535	0.9584
A103-7(B)	TV	MRS 73-34	0.7058	0.5496	1.1600	0.6367
A103-37	TV	MRS 73-34	0.4190	0.6345	1.1192	0.3632
A103-69(B)	TV	MRS 73-34	0.5157	0.6995	1.2691	0.4298
LAKE 30708	MGW	AZ:A:14:46	0.4339	1.4683	1.8114	0.1343
LAKE 20334A	MGW	AZ:A:14:46	0.0458	0.4696	0.5411	0.3406
LAKE 20334B	MGW	AZ:A:14:46	0.7441	0.2257	0.9049	0.8868
LAKE 20362	MGW	AZ:A:14:46	0.1852	1.4355	1.5994	0.3328
LAKE 20335	MGW	AZ:A:14:46	0.1422	0.9500	0.8934	0.3700
LAKE 20890B	SV	AZ:A:14:232	0.3281	1.0776	1.8918	0.2807
LAKE 20923B	SV	AZ:A:14:232	0.0685	0.2067	0.8310	0.6022
LAKE 20897	SV	AZ:A:14:232	0.1767	0.4700	1.0976	0.3268
LAKE 20923A	SV	AZ:A:14:232	0.2270	0.1596	1.3633	0.6120
LAKE 20890A	SV	AZ:A:14:232	0.1215	0.2468	0.9715	0.4985
LAKE 20334	TV	AZ:A:14:46	0.1386	1.1286	1.0463	0.2604
LAKE 20321	TV	AZ:A:14:46	0.1105	0.9285	0.7625	0.3355
LAKE 307076	TV	AZ:A:14:46	0.1407	1.1069	0.8980	0.3086
LAKE 30707	TV	AZ:A:14:46	0.1815	1.0883	1.1522	0.3250
LAKE 303707	TV	AZ:A:14:46	0.1492	0.5389	0.9096	0.4943

Table A.3: Calculated relative percentages of fatty acids present in samples

Catalog #	Ware	Location	Medium Chain %	C18:1%	C18:0%
A103-58	MGW	MRS 73-34	15.5861	13.2433	22.4431
A103-17	MGW	MRS 73-34	13.6999	17.9472	15.0293
A103-89	MGW	MRS 73-34	10.8249	17.8339	26.6894
A105-1	MGW	MRS 73-105	9.5257	22.6225	26.8642
A105-29	MGW	MRS 73-105	19.2563	14.9609	16.6763
A105-42	SV	MRS 73-105	10.4227	9.2054	42.7058
A105-46(A)	SV	MRS 73-105	9.5685	8.0727	40.2391
A105-54	SV	MRS 73-105	16.3811	16.9753	23.6172
A105-33	SV	MRS 73-105	23.7027	14.1275	17.1834
A105-46(B)	SV	MRS 73-105	21.4709	6.5704	29.5284
A103-69(A)	TV	MRS 73-34	11.5516	22.8193	19.3692
A103-7(A)	TV	MRS 73-34	16.7611	14.9364	23.9050
A103-7(B)	TV	MRS 73-34	14.2314	14.0862	26.5839
A103-37	TV	MRS 73-34	10.4113	10.4362	32.3020
A103-69(B)	TV	MRS 73-34	16.5313	9.4275	27.8727
LAKE 30708	MGW	AZ:A:14:46	17.1017	5.5784	22.6648
LAKE 20334A	MGW	AZ:A:14:46	4.4698	4.2399	56.9372
LAKE 20334B	MGW	AZ:A:14:46	8.7443	21.5181	25.2829
LAKE 20362	MGW	AZ:A:14:46	13.8193	2.3269	29.6338
LAKE 20335	MGW	AZ:A:14:46	12.9260	7.9430	36.7050
LAKE 20890B	SV	AZ:A:14:232	17.9981	6.9171	22.2679
LAKE 20923B	SV	AZ:A:14:232	6.6669	20.3671	36.8174
LAKE 20897	SV	AZ:A:14:232	10.0748	23.8364	25.2215
LAKE 20923A	SV	AZ:A:14:232	5.7175	54.0009	12.7871
LAKE 20890A	SV	AZ:A:14:232	7.4301	31.5816	26.2253
LAKE 20334	TV	AZ:A:14:46	13.5029	2.8811	38.2329
LAKE 20321	TV	AZ:A:14:46	10.6648	5.8398	43.1545
LAKE 307076	TV	AZ:A:14:46	12.5370	5.5222	38.6805
LAKE 30707	TV	AZ:A:14:46	10.8478	10.2685	30.4562
LAKE 303707	TV	AZ:A:14:46	9.4382	12.0372	36.5912

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1996 Population Growth, Agricultural Intensification, and Culture Change among the Virgin Branch Anasazi, Nevada. *Journal of Field Archaeology* (23)1: 55-76.

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- 2013 Cacao Consumption during the 8th Century at Alkali Ridge, Southeastern Utah. *Journal of Archaeological Science* 40(4): 2007–2013.

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- 2008 Animal Resource Exploitation among the Virgin River Puebloans in the American Southwest. *Journal of Field Archaeology* 33(4): 449–459.

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- 1991 *The Shivwits Plateau Survey: Archeology at Lake Mead National Recreation Area*. Tucson: Western Archaeological Conservation Center.

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Wright, Barton Allen

- 1954 *Excavation of Catclaw Cave, Lower Colorado River*. MA thesis, Department of Anthropology, University of Arizona.

Curriculum Vitae

BRENNA L. WILKERSON

(256) 551-2281 (M)	6530 Annie Oakley Dr.	
(702) 848-4828 (H)	Apt. 2824	brenna.wilkerson1@gmail.com
	Henderson, NV 89014	

EDUCATION

August 2016 *M.A. Anthropology* | University of Nevada, Las Vegas | Department of Anthropology

May 2013 *B.A., Anthropology, summa cum laude* | Auburn University, Auburn, AL | Department of Sociology, Anthropology, and Social Work | Major GPA: 4.0

May 2013 *B.A., French, summa cum laude* | Auburn University, Auburn, AL | Department of Foreign Languages and Literatures | May 2013 | Major GPA: 4.0

RESEARCH AND FIELD EXPERIENCE

Spring 2016 *Intern* / Lost City Museum | Jerrie Clarke, Museum Director

- Created museum exhibit on diet and subsistence strategies among prehistoric groups in southern Nevada and northern Arizona

Fall 2014 *Intern* | Nevada Site Stewardship Program (NSSP) | Nevada State Historic Preservation Office | Dr. Samantha Robinson, Nevada Site Stewardship Coordinator

- Trained volunteer site stewards to monitor archaeological sites during NSSP Basic Program Training
- Managed NSSP database by entering monitoring reports, updating site information, and filing program paperwork

Summer 2014 *Student Crew Member* | Shivwits Field School | University of Nevada, Las Vegas | Dr. Karen Harry, field school director

- Excavated at a Virgin Branch Puebloan site in Grand Canyon-Parashant National Monument

Fall 2011 to Spring 2013 *Archaeology Lab Assistant* | Auburn University, Auburn, AL

- Analyzed collections in the Auburn University Archaeology Lab
- Conducted pedestrian survey of private property in Lee county, AL

Summer 2011 *Student Crew Member* | Auburn University Field School

- Excavated and surveyed two archaeological sites in Macon County, AL
- Analyzed artifacts collected during this field school

TEACHING EXPERIENCE

Fall 2014 to Spring 2016 *Academic Success Coach* | Academic Success Center | University of Nevada, Las Vegas, NV

- Met with caseloads of 70-90 at-risk first year students one-on-one to help them develop beneficial study skills, time management strategies, and test-taking skills
- Met with 67 Honors students one-on-one for Academic Success Coaching sessions | Spring 2016
- Presented information about study skills, time management, test-taking, and critical reading to current UNLV students during Success Series Workshops
- Collaborated with UNLV admissions officers and presented information about campus resources at local high schools during Next Steps (for admitted high school seniors)
- Presented information to incoming freshmen, transfer students, and students' family members about academic resources during New Student Orientation | Summer 2015
- Created and supervised the Summer 2015 Academic Success Coach Training (40-hour training) which included researching discussion topics and activities, creating the schedule, and coordinating resources panels and campus tours with several departments
- Interviewed candidates for Fall 2015, Spring 2016, and Fall 2016 Academic Success Coaching positions

Fall 2013 to Spring 2014 *Tutor for Trio Upward Bound* | Nevada State College, Henderson, NV

- Tutored in math, biology, chemistry, French, and other subjects at four high schools in Las Vegas and Henderson, NV
- Assisted teachers during Saturday school for program participants at Nevada State College

Fall 2011 to Spring 2013 *Supplemental Instruction Leader* | Academic Support, Auburn University, Auburn, AL

- Led group tutoring sessions (five to 125 students) for Introduction to Biology (BIOL 1000) (8 hours/week) | Fall 2011 and Fall 2012
- Led group tutoring sessions for Survey of Life (BIOL 1010) (8 hours/week) | Spring 2012 and Spring 2013

PRESENTATIONS

- 2016 **Wilkerson, Brenna.** *The Proof is in the Pots: Comparative Residue Analysis of Upland and Lowland Virgin Branch Puebloan Ceramics.* Poster presentation at the UNLV Graduate and Professional Student Association Research Forum.
- 2015 **Wilkerson, Brenna.** *The Proof is in the Pots: Comparative Residue Analysis of Upland and Lowland Virgin Branch Puebloan Ceramics.* Presented at the Three Corners Conference, Las Vegas, NV.
- 2015 *Nevadans for Cultural Preservation* | Presented to the Nevada Naturalists, University of Nevada, Reno Cooperative Extension | May 20, 2015.
- Workshop on local fibrous plants, archaeological artifacts made from natural fibers, and preserving archaeological sites and artifacts
- 2012 Ashworth, Danielle and **Brenna Wilkerson.** *Influence of Age and Status on Mortuary Art in Alabama.* Presented at the annual meeting of the Alabama Academy of Science, Tuskegee, Alabama. | February 24, 2012

SERVICE

- 2015 to 2016 *Volunteer* | Department of Anthropology Open House | University of Nevada, Las Vegas
- 2015 *Volunteer* / Dawson College Bound Summer Enrichment Program
- 2015 to present *Volunteer* | Nevadans for Cultural Preservation
- Led 30-minute presentation about IMACS forms and other types of paperwork for recording archaeological sites for Site Condition Assessment Training for current Nevada Site Stewards
 - Trained 16 site stewards in the field to perform site condition assessments and record site information
 - Created accompanying section on IMACS forms and site paperwork in the Site Condition Assessment Training Manual
- 2015 *Volunteer* | Nevada Site Stewardship Program
- Performed site condition assessments of historic and prehistoric sites near Belmont, NV in cooperation with USFS archaeologists
- 2015 *Career Day Presenter* / Decker Elementary School, Las Vegas, NV
- 2014 *Volunteer* | Southwest Symposium | University of Nevada, Las Vegas

SCHOLARSHIPS AND RECOGNITIONS

- Spring 2016 *Honorable Mention* | Poster presentation at GPSA Research Forum
- Spring 2016 *Graduate & Professional Student Association (GPSA) Sponsorship* | Awarded \$350.00

Spring 2016 *Friends of World Anthropology Scholarship* | Awarded \$350.00
 Spring 2016 *Edwards and Olswang Grant* | Awarded \$330.00
 Spring 2013 *Auburn University Honors College* | Completed Bachelor's level requirements
 and graduated with honors
 2009 to 2013 *Auburn University Dean's List*
 2009 to 2013 *Auburn Founder's Scholarship* | Merit-based tuition waiver (\$8,000 per year)

MEMBERSHIPS

2013 to present *Nevadans for Cultural Preservation (NVFCP)* / President
 2013 to present *Lambda Alpha (Anthropological Honors Society)*
 2013 to present *UNLV Anthropology Society*
 2011 to 2013 *Southeastern Archaeological Conference (SEAC)*
 2010 to present *Pi Delta Phi* (French Honor Society)