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# FIRE-AFFECTED ROCK IN INLAND SOUTHERN CALIFORNIAN ARCHAEOLOGY: AN INVESTIGATION INTO DIAGNOSTIC UTILITY

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# FIRE-AFFECTED ROCK IN INLAND SOUTHERN CALIFORNIAN ARCHAEOLOGY:

# AN INVESTIGATION INTO DIAGNOSTIC UTILITY

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A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

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In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

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by

Shannon Renée Clarendon

December 2017

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ABSTRACT

The post-firing variability of fire-affected rock (FAR) recovered from a stone-cooking platform within a prehistoric stone grill was examined. This examination tested the physical properties of FAR recovered from site CA-SBR-3773, located the Crowder Canyon Archaeological District in San Bernardino County, California. There is a lack of archaeological research in this area of Southern California; however, this project established a fundamental perspective of thermal feature reuse and episodes of firing activity for prehistoric cooking features by examining the physical changes FAR experienced due to various heat exposures. Regional archaeologists often encounter these features as they speckle the landscape of upland desert regions in California.

This research is an experimental project that compares the cultural stones' properties to those of non-cultural origin, which have been fired various times during controlled replicative experimentation. The end comparison identifies the FARs' change in physical conditions. Repeated exposure to high temperatures has a direct relationship to the stability and matrices of rock, in this particular case, schist (Yavuz *et al*. 2010). As the stone is repeatedly exposed to high temperatures, its durability and structural components begin to deteriorate. This deterioration can be measured and compared to pre-fired physical properties. One of these physical properties is the stones' porosity, which is calculated using the measured absorption rate of stone before and after exposure to firing episodes. These firing episodes are meant to approximate the cultural use of

these stones during prehistoric cooking episodes. The results of the experiment show that FAR may have some diagnostic capabilities to infer multiple firing episodes, confirm facility reuse, and support suggested mobility with respect to available resources and temporal episodes through accelerator mass spectrometry (AMS) dating and other analyses such as micro-botanical analysis.

# ACKNOWLEDGEMENTS

As the famous proverb states “It takes a village.” It has, indeed, taken a village to produce this manuscript, and I would like to acknowledge those who have helped me along this two-and-a-half-year journey.

I owe my sincere gratitude to Dr. Amy Gusick. Without her I would not have a been inspired to give back to the community, be an active member of the University, nor would I have a piece of coherent research to present in this thesis. I consider myself lucky to have had her as an advisor and professor.

I want to extend my deepest gratitude to Dr. Robertshaw for his belief in me academically, and for allowing me the opportunity to advance my education. Without the opportunity he has given me the research presented here would not have been possible.

I would like to thank Laura Chatterton, John Eddy, and Bill Sapp, for providing access to my experimental materials, for eliciting the line of research questions, and for inspiring my overall thesis research, respectively.

I owe a great deal to Julie Scrivner, who inspired my overall love and appreciation for California archaeology.

I would also like to thank the faculty and staff of the Anthropology Department at California State University San Bernardino. This department has helped mold me into an exceptional student, and productive archaeologist. For these reasons I am very grateful for the time and energy this department invested in my academic success.

# DEDICATION

I dedicate this manuscript to the three most important people in my life:

To my Mother, Debra Holmes, for her continuous faith and support both physically and emotionally throughout my life. She was and will remain the strongest woman I have ever met.

To my grandfather, John Thomas Holmes, for always inspiring me to be a compassionate person, and for his undying confidence in me and my pursuit of higher education.

To my daughter, Sloane, although she is new to my life, she has ignited a fire in me that no one had been able to do. The completion and editing of this manuscript was motivated by my desire to inspire her one day.

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# CHAPTER ONE

# INTRODUCTION

There are many archaeological sites across upland desert regions of Inland Southern California that can contain thermal features, or as some archaeologist call them, “cooking facilities” (Thoms 2009). Different terms have been used to categorize these thermal features. Terms such as hearth, cooking feature, earthen ovens, roasting pits, etc., have been used by regional archaeologists to differentiate between the typologies of these thermodynamic features. While these thermal features differ in composition they are very common within mountainous regions of Southern California and are the focus of this thesis. One major component of a stone grill is its stone cooking platform. These platforms produce fire-affected rock (FAR), and its subcategory, fire-cracked-rock (FCR). These features, and the FAR contained therein have been studied broadly, but these studies have yet to yield information beyond the scope of rudimentary descriptions, typologies, and terminologies, most of which, only describe the possible functions of these features. Because FAR has been considered a catch-all category of non-diagnostic artifacts that are normally considered of little analytical value, typical recordation of FAR consists of recording bulk weight and sometimes count. Recordation and other archaeological writings, including drawings, typically depict these features as a sign of cooking activity (Crawford 2011). Hildebrandt and Darcangelo (2008:59) argue this point with the following examples, “the feature was likely to represent an earth oven for cooking or drying fish,” or “the hearth was not associated with structural remains, which probably means that some cooking activities took place outside during the warm seasons.”

White (1980) discussed clusters of FAR identified in Southern California and commented on the lack of interest in these features by some archaeologists. He noted the general application of terms such as “fire-pit,” “oven” or “cluster” to thermal features. White further argued that these terms were utilized as a common way to record the feature’s form and function. He stated, “if projectile points and other artifacts are composed of traits which make them significant enough to systematically categorize, describe, and discuss at length, why then should a site feature with every bit as much claim to functional importance be handled in such a cavalier manner?” (White1980:67).

Current writings and research suggest that archaeologists will continue to normalize the catch-all terms and definitions that merely suggest function while continuing to negate further analysis on thermal features and their FAR constituents. It is my opinion that in negating further analysis of FAR, the archaeological record loses valuable data that may contribute to an understating of the subsistence economy and mobility practices of the region in which clusters of FAR occur.

During the past twenty years, archaeological labs in California have been carefully processing microscopic materials recovered from thermal features *in* *situ* with FAR and have been analyzing these particles through various techniques such as flotation and fine-mesh screening. These techniques recover the remains of resource particles too small to identify while in the field, and identify floral and faunal remains that facilitate research questions and studies which can infer seasonal movements, seasonal occupations, and food procurement strategies. Many times, these inferences are made within a human behavioral ecological framework. This same type of attention to analytical detail has not been paid to the thermal feature itself or its FAR constituents.

The purpose of this research is to provide additional analytical capabilities to FAR by determining if identification of thermal feature reuse is possible by testing the physical properties of FAR specimens recovered from thermal features in the Crowder Canyon Archaeological District. Crowder Canyon is a region in San Bernardino County where prehistoric inhabitants left hundreds of thermal features across the landscape. These features are thought to have been used to process yucca (*Yucca schidigera*) using manzanita (*Arctostaphylos sp.)* as fuel, both species of which are abundant in the region. The experimental portion of the current research consisted of measuring the physical properties of FAR recovered from a stone grill and then comparing these stones' properties to those of a control group of non-cultural origin that have been fired various times during replicative experiments. This comparison was used to describe the change in physical properties of the stones found in archaeological contexts, focusing on the porosity of the stone.

My initial inquiries into the phenomenon of site reuse were formulated by my curiosity and drive to convert a piece of material culture, in this case FAR within prehistoric grills, into a diagnostic tool, which may ultimately infer site use and reuse. The cooking platform within the stone grill is a cultural mainstay and is typically recycled, with only the fill being thrown out (Milburn 1998). As such, the stones comprising a grilling platform are selected and arranged to withstand multiple uses, and this research is an attempt to create a new method that can inform on the number of firings of a stone grill. Considered in conjunction with additional site information, the data generated from this analytical technique may contribute to the understanding of prehistoric cultures that inhabited the upland desert regions, and similar landscapes within Southern California, through inferences into site reuse.

# CHAPTER TWO

# STUDY AREA BACKGROUND

## Environmental Background

The Crowder Canyon Archaeological District is located in the Cajon Pass (Figure 1). The Cajon Pass is a break in the San Bernardino and San Gabriel Mountain Ranges. In the past these two mountain ranges were connected, however the “pass” as local call it, was created by the San Andreas Fault. The rift in the mountain ranges occurred when two tectonic movements caused the North American Plate and the Pacific Plate to collide with each other. Over the years the rift between the two plates expanded into a valley carved out by flowing water and additional tectonic activity (Feller 2017). The plates continued to move, pulling away and against one another producing new water sources and canyons. The West Cajon Valley or “amphitheater” was created by these natural processes and yielded the schist bearing canyons seen in Figure 2 (Feller 2017). The Crowder Canyon archaeological district, which is the focus of the current research, is found in this passage called the Cajon Pass. “Cajon” is a Spanish translation of “box”, and this term is used in the geographical community to convey box-like canyons.

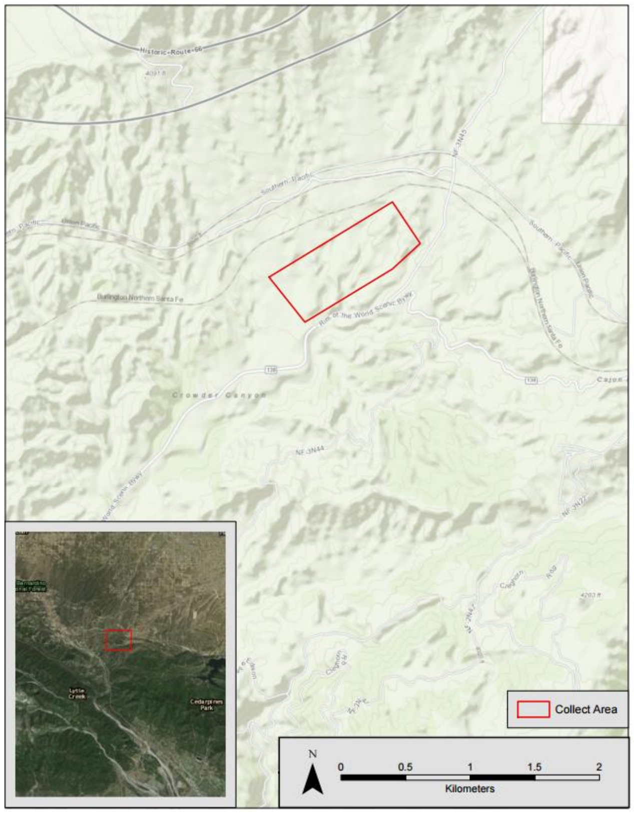



Figure 1. Crowder Canyon Archaeological District / Study Area

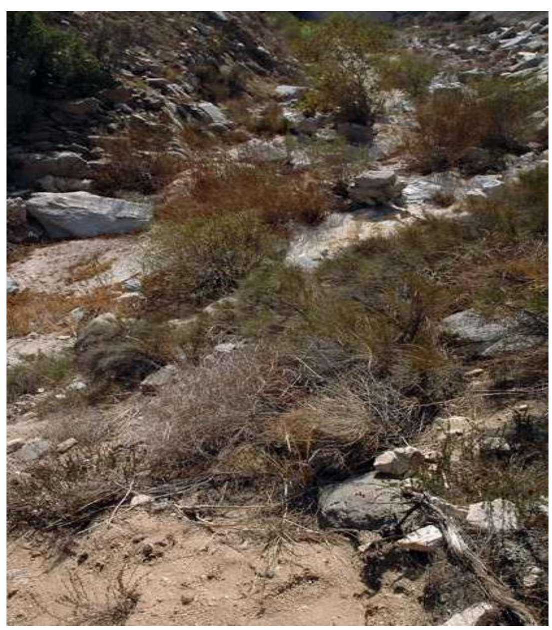


Figure 2. Schist Eroding out of Crowder Canyon

Important Resources: Yucca and Manzanita

Based on the ethnographic record for the Crowder Canyon area, yucca and manzanita were widely available and relatively easy to obtain. These two resources are still found today in great quantities within the project area. Manzanita can range in size from small bush like clusters and they can occupy various climate zones. There are over 40 native species of manzanita in California. The species that is most commonly found in the Cajon Pass, is (*Arctostaphylos glauca*). This type of manzanita can exceed 13 feet in height and can be found at elevations starting at 2,209 feet up to the pass's summit. Besides the red trunk, this species of manzanita has foliage that begins as sticky leaves; later their surfaces smoothen and they stand erect on the branches. Manzanita is a viable and excellent fuel source because it is a very heavy dense wood that can burn longer and hotter than other local woody sources (Milburn 2004).

Yucca is very important in terms of subsistence, ritual, and social organization for the Serrano people of the Transverse mountain regions and the Cahuilla people of the Peninsular mountain regions of Southern California (Bean and Saubel 1972; Sutton 1988; Sobolik 1996). McCarthy's (2011) comparative and experimental research in the Cahuilla ancestral territory, just southeast of the study area, focused on the varying forms of cooking features and processing techniques surrounding yucca as an article of subsistence and represents the most extensive research on this subject conducted to date. This thesis utilizes

McCarthy's (2011) research as an analogy for resource preparations practiced by the Serrano, who occupied Crowder Canyon.

Research which details the types of cooking features utilized for certain portions of the yucca plant, and includes contemporary harvesting of yucca, provides a clear picture of the types of cooking features needed to process this resource (McCarthy 2011). McCarthy's research also suggests that Native American groups that inhabited the region processed yucca as part of a social ritual (McCarthy 2011). Consideration of this research in conjunction with ethnographic accounts and biological and environmental data provides an overall view of how yucca usage evolved into a significant facilitator of cultural tradition. Its specific processing and consumption may constitute a form of social ritual in which all members of the community were involved.

Land use and resource exploitation by the prehistoric inhabitants of Crowder Canyon were largely driven by subsistence decisions and clan organization on a landscape scale. Culturally significant plant resources such as yucca were integral in both subsistence decisions as well as trade (Bean and Saubel 1972). As a food item, yucca was an important resource for the groups in the region, but its elevation-specific growth and tribal territory considerations limited its availability to specific tribes in the region, making it an excellent trade item. Both McCarthy's research and the ethnographic record suggest that prehistoric peoples of Crowder Canyon exploited yucca as a dietary staple, for utilitarian purposes, and as a trade item for generations (Bean and Saubel 1972; McCarthy 2011; Kowta 1969).

## Cultural Background

Human occupation of mainland Southern California is believed to have its origins approximately 12,000 years ago. The following sections will detail five cultural periods of occupation within California that span 12,000 years B.P. to the present. These periods include: The Paleo-Indian Period, the Early Archaic Period, the Archaic or Milling Stone Period, the Intermediate Period, and the Late Prehistoric Period.

### Paleo-Indian Period/Terminal Pleistocene (12,000 to 10,000 B.P.).

The first Southern Californians are described as gatherers who also practiced big-game-hunting. Gathering, a staple of smaller logistical patterned communities, gave way to the exploitation of megafauna which included species like mammoths. Fluted point assemblages included spears and blades and were identified locally and compared to Clovis Paleo Indian manufactured materials. These manufactured items were found to be similar both temporally and morphologically. This typological and temporal similarity produced an analogous date for the local California lithics (Moratto 2004). However, archaeological evidence of occupation during the Paleo Indian Period in California rests within a few assemblages producing very few fluted points identified within temporary camp sites. luted points have been identified and recorded in Imperial County as well as San Diego County. Most of the assemblages containing multiple fluted points are located near Pleistocene lake shores like those found in the Mojave Desert and San Juaquin Valley (Rondeau 2009).

Early Archaic Period/Early Holocene (10,000 to 8,000 B.P.).

Around 10,000 B.P. a warming trend facilitated a shift in subsistence strategies from the exploitation of big-game-hunting to gathering with an intermittent reliance on small game. During this period, the Mojave Desert lakes, where assemblages were once accompanied by points, present less evidence of Early Holocene occupations. However, coastal sites in Santa Barbara and San Diego Counties, as well as sites further inland in Riverside County have produced further evidence of occupation during the Early Holocene (Erlandson 2001; Goldberg 2001; Grenda 1997; Gallegos 1991; Koerper *et al*. 1991; Warren 1967). These sites contain artifacts such as leaf-shaped points and knives, and other artifacts associated with this period (Koerper *et al*. 1991).

Archaic or Milling Stone Horizon/Middle Holocene (8,000 to 3,000 B.P.)

This period in Southern California prehistory is associated with milling tools such as those found in coastal sites in San Diego County including those at the Harris site (CA-SDI-149) (Gallegos 1991; Koerper *et al*. 1991). Typical archaeological sites located on the coast during this period are comprised of shell middens and thermal features. Milling artifacts such as hand stones or “manos”, “choppers” and other ground stone tools and “gaming pieces” are prevalent throughout these sites and indicate the Milling Stone Horizon. The period's funerary practices were categorized by internment, with the inclusion of milling tools.

As mentioned previously The Milling Stone Horizon was categorized by the cultural material identified in sites along the coast, however, there are inland manifestations of this temporal period with sites containing similar artifacts, minus the shell middens, located in Rancho Cucamonga, The Cajon Pass and Prado Basin (Wallace 1955; Salls 1983; Goldberg and Arnold 1988; Kowta 1969; Basgall and True 1985). The shift in subsistence practices to plant procurement suggests smaller populations during the period. These populations consisted of small groups moving in seasonal rounds from the coast to inland settlements and vice versa.

<u>Intermediate Period/Late Holocene (3,000 to 1,350 B.P.)</u>

"Metates" and "Manos" were a mainstay during the Milling Stone Horizon occupation; however, the presence of mortars and pestles characterizes the Late Holocene Period and suggests a focus on acorn processing. The identification of these artifacts implies more sedentary patterns of mobility due to the laborious nature of acorn processing. Acorns are considered a high-ranking food source in terms of caloric intake and can be stored for long periods of time in case of seasonal resource pressures. Settlement patterns began to shift towards sedentary systems, but seasonal rounds continued to take place. The winters consisted of camping near main water sources with temporary camps utilized for resource procurement during the rest of the year (Kowta 1969).

It is postulated that the inland areas utilized acorn processing later in the period than coastal occupations. The evidence behind this assumption stems from the absence of mortars and pestles and the continued frequency of metates and manos in the beginning of the period (Kowta 1969; Goldberg and Arnold 1988). Based on the assemblages identified on the coast, which contain several examples of acorn processing tools, it can be assumed that the manufacture of these tools and processing of acorns occurred first within coastal communities and was adopted by inland inhabitants later in the period (Goldberg 2001).

Late Prehistoric Period/Late Holocene (1,350 B.P. to Spanish Contact [A.D. 1769]).

The introduction of the bow and arrow, along with further warming trends during the Late Holocene, helped to facilitate a major shift in settlement patterns. The period began with a semi-sedentary strategy and shifted to permanent village communities situated by permanent water sources near several types of exploitable local resources. By the time the Spanish arrived these villages were populated by upwards of 250 people. These villagers set up strategic logistical hunting and foraging strategies that consisted of small gathering and hunting parties who built temporary camps outside of the village, in areas of high resource availability. Keeping within territorial boundaries inhabitants would procure food resources and process them in these temporary camps (Goldberg *et al.* 1988). These temporary sites can be identified archaeologically by the presence of milling stations, manos, and metates. The presence of FAR at these temporary campsites suggests food preparation in thermal features and thus multiple-day stays.

The Medieval Climatic Anomaly (MCA) is postulated to be the cause of the intense warming period and was accompanied an extremely dry climate, facilitating the strategic decision to settle near permanent water sources. “Droughts during the MCA were severe enough to cause problems for residents of poorly watered areas of Native California” (Jones and Klar 2007:302).

## Archaeological Background

### Study Area: Crowder Canyon (Formerly Coyote Canyon)

Crowder Canyon is considered a “corridor” that was produced by natural processes allowing trade and movement between upland desert regions and coastal settlements. The study and collection areas are located near Crowder Creek which holds enough water on a seasonal basis to support a variety of food resources, plant and animal alike. The Crowder Canyon Archaeological District includes several prehistoric sites. These sites include “short-term habitation sites,” “working/ processing sites,” and “temporary camp sites” (Kowta 1969). Furthermore, this area is considered by local archaeologists as the “furthest inland manifestation of the Milling Stone Horizon discovered in California” (Kowta 1969).

In the 1940s the San Bernardino County Museum Association began investigations at Crowder Canyon and identified several sites. Surveys and small excavations were conducted; however, the information gained from these early investigations have yet to be analyzed and a report has never been written. The Crowder Canyon collections currently held at the San Bernardino County Museum, do not include material identified during the 1940s investigations (Basgall and True 1985; Kowta 1969).

Later excavations, conducted in the 1960s, contracted by the Gas Company, unearthed Late Milling Stone Horizon artifacts. In 1969, Kowta drafted a report detailing the results of the Gas Company's investigation and proposed that the high frequency of tools, such as scraper planes, suggest the exploitation of fibrous plant material which categorizes the Milling Stone Horizon Period.

In the 1970s, the California Department of Transportation (Caltrans) entered the archaeological fray. During this decade Caltrans contracted archaeologists to survey the canyon, under the newly implemented Section 106 regulations, in preparation for infrastructure improvements. The final report from this work consisted of what current archaeological technicians would call site updates or site monitoring. The previously recorded archaeological sites and their constituents were relocated and recorded in what amounts to a shortened memo of recommendation. The memo did, however, jump-start more interest in the area and facilitated further evaluation of the sites located in Crowder Canyon. This evaluation required extensive testing of the area which began in 1973. Over a three-year span, Crowder Canyon archaeological testing initiatives took place and produced the most extensive investigations the canyon would experience for decades to come (Basgall and True 1985). The initial report generated from these intense investigations was fundamental and constituted the background information in forthcoming Caltrans reports.

In 1975, Crowder Canyon Archaeological District was nominated for listing on the National Register of Historic Places (NRHP) by Alan Garfinkel. His argument for significance lay with the integrity of the associated sites with periods of occupation spanning across the Milling Stone Horizon. He further argued the significance of the district's ability to produce future data that could provide information and understanding pertaining to the prehistory of the region. The Crowder Canyon District was listed on the National Register of Historic Places (NRHP) in 1976 (Eddy and Garfinkel 2009).

In their 2009 paper presented at the Society for California Archaeology annual meeting, Eddy and Garfinkel clearly state that the investigations conducted throughout the sixties, seventies, and eighties in Crowder Canyon constitute an ushering in of further developments and research practices in Cultural Resource Management:

> These early Crowder canyon studies nurtured cultural resource management from an agency-sponsored volunteer practiced salvage exercise, to a full-fledged archaeo-business with justly compensated professional and validly framed research that provides numerous jobs to archaeologists and historians who otherwise would not have

found an outlet to practice their skills [Eddy and Garfinkel 2009:6-7].

It is important to note the importance of the archaeological investigations conducted within Crowder Canyon, especially those studies from the 1970s which produced significant prehistoric knowledge of the region and led to the District's listing on the NRHP. This information, as argued by Peregrine (2004), allows cross-cultural analogies that regional archaeologists can use to differentiate or compare cultural traditions. As such, previous studies, as made clear by Kowta (1969), attempted to explain the difference in material culture found in sites associated with the Milling Stone Horizon. The work completed in The Crowder Canyon Archaeological District provides further understanding of the region, and we now have the ability to contrast and compare the characteristics of these sites to those of various temporal periods and various cultural traditions across the region and California more broadly.

# CHAPTER THREE

# THERMAL FEATURE BACKGROUND

## The Development of Prehistoric Cooking in Upland Desert Regions of Inland Southern California

Thermal features, enter the archeological record of the Transverse Mountain Range by approximately 7600 years B.P. (Milburn 2016). These thermal features found can be attributed to food processing done by Native Americans in the region. During the Archaic Period, (10,000-5000 B.P.), Native Americans procured and processed food from mountain regions, focusing mainly on acorn, juniper berries, roots/tubers, yucca, and agave. The utilization of thermal features saw a significant expansion by 2300 B.P (Thoms 2009). This increase can be observed throughout the archaeological record of the region as researchers identified and recorded an increase in frequency of occurrences (Black and Thoms 2014; Schneider *et al*.1996; Thoms 2008, 2009). This increase is postulated to have a direct correlation with increased populations, sedentary settlement patterns, and areas that experienced resource intensification (Thoms 2009).

During the Late Archaic Period (6000-40000 B.P.) Native American subsistence strategies in the upland regions of the Santa Rosa Mountains shifted to primary plant foods, including yucca and piñon nuts. By 2000 B.P., earth ovens became obsolete, and stone grills were more prevalent in the archaeological record. These grills proved to be fuel efficient and became prevalent across the upland desert landscape of the Cajon Pass and eastern portions of the Transverse Mountain Range (Milburn 2016).

## Models of Hot-Rock Cookery

As stated previously, the stone-lined ovens appear in the archaeological record of the Transverse Ranges by at least 2000 B.P. (Milburn 1998, 2004). The introduction of this new cooking technology facilitated the replacement of earlier cooking technologies, such as earthen pits, in the eastern San Gabriel Mountains and in the Cajon Pass (Milburn 1998, 2006a). Stone-lined thermal features require less fuel and are more efficient in radiating higher temperatures for longer periods of time. Conservation of fuel appeared to be important during periods of resource intensification, and the efficiency of the newly adapted technology provided more time for food procurement and processing in locations that yield multiple features across the landscape (King 1993; King *et al*. 1974:17). The lack of thermal features in the archaeological record after about 400 B.P suggests a decrease in the utilization of these features just before European contact. It is possible that this decrease in stone grills is related to an introduction of even more efficient cooking technologies during the Protohistoric Period that required even less fuel. It is also possible that Native populations decreased during this period (Thoms 2003).

In Thoms' proposed model (Figure 3), "intensification of cook-stone technology is a manifestation of land-use intensification triggered by population packing" (Thoms 2009:573). Here Thoms makes the argument that the presence of more features identified in the archaeological can be used to infer two correlations: an increase in population density and a shift in available resources. Figure 3 expresses Thoms' 2009 model for the "expected temporal patterns in the use of different kinds of hot-rock cooking features," taking into consideration the change in morphology of the thermal features over time with respect to labor costs.

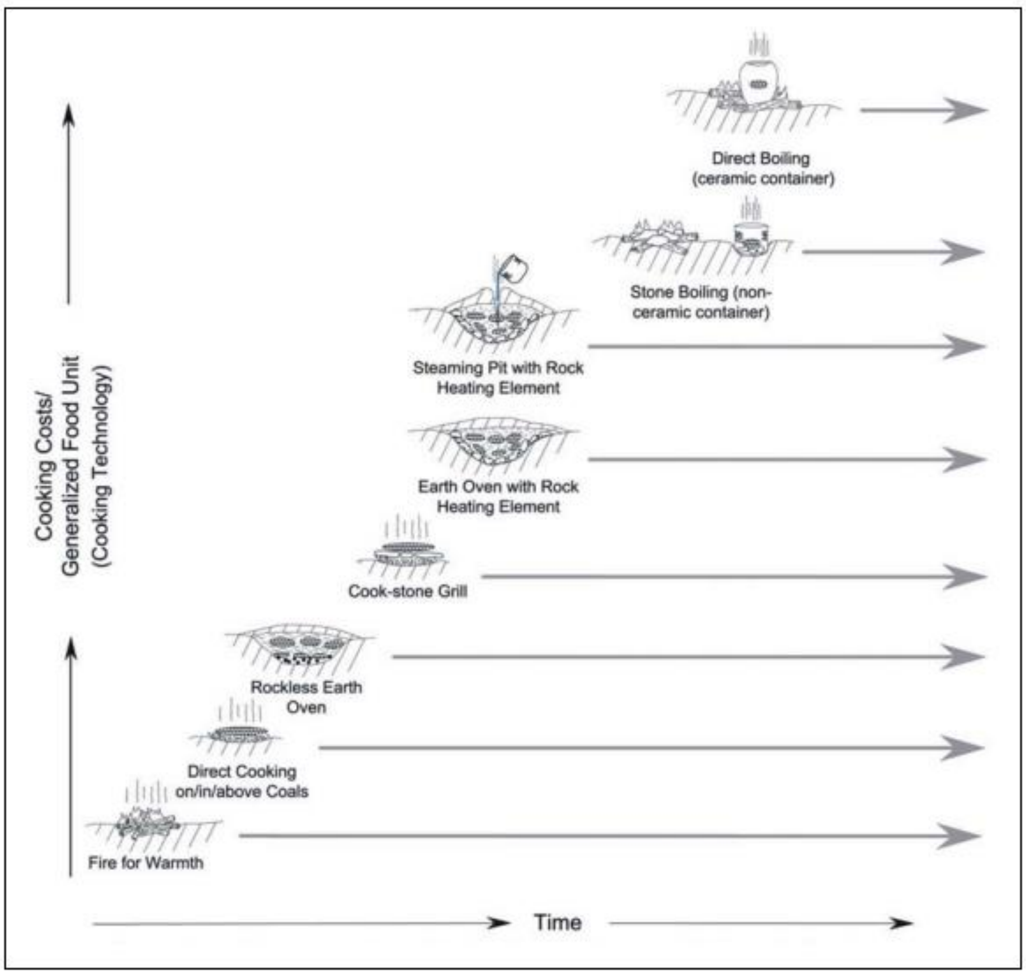



Figure 3. Expected Temporal Patterns, from Thoms (2009)

According to Thoms' model, the use of stones within cooking features increases as land use intensifies. As such, an increase in thermal features suggests an overall increase in the appearance of FAR across time. Following Thoms' line of thinking, we should expect to observe an increase of more efficient features over time, and shifts in substance procurement and mobility patterns by the inhabitants of the associated period.

The Great Basin experienced a shift in subsistence strategies just after the Pleistocene period. Populations during this period situated themselves in small groups dispersed across the landscape. This required a highly focused strategy that utilized high caloric food resources including yucca, as well as smaller animals hunted within the boundaries of their territories at lower elevations (Jones *et al*. 2003:6-8, 30-31). This early strategy utilized crude thermal features such as open-air firing pits, which are terrible in terms of archaeological preservation. This form of inefficient thermal feature was utilized through most of California prehistory, but this form of feature type decreases in frequency the archaeological record as more efficient thermal features became more prevalent (Thoms 2009).

In the Mojave Desert, open firing pits make an appearance in the archaeological record at approximately 8000 B.P. as evident at CA-KER-3939 (Gardner *et al*. 2006). Several hundred years later, about 7600 B.P., they appear in the San Gabriel Mountains at CA-LAN-3013 (Milburn 2002, 2004). As Thoms' model and the aforementioned examples prove, thermal feature technology can identify shifts in strategies pertaining to mobility and resource procurement from low elevations to higher elevations where food requires more intense heat and longer cooking times.

The upland desert regions of The Transverse Ranges experienced a notable rise in the number of thermal features that include FAR at approximately 2300 B.P. During this time, the focus of most upland desert inhabitants still relied on strategies that utilize a broad variety of resources. However, some populations of these regions still actively sought out the high caloric primary foods such as yucca (Earle *et al*. 1995:2.14-2.23). It is important to note once more that the majority of resources cooked in thermal features appear to have been sourced from yucca, an important regional staple that can be stored for over a year after cooking (Zigmond 1981).

## Distribution of Identified Cooking Features in Region of Study

Milburn's 2009 study area within the Transverse Mountain Range comprised 160 locations containing FAR within thermal features, and overlaps the study area that is the focus of this thesis. Milburn (2004, 2009) documented features over three different geographical locations including 16 thermal feature sites in the Cajon Pass (Figure 4). His distribution model of thermal features finds higher densities in upper mountain areas between 3,000 feet (ft) and 5,000 ft. Clusters of FAR were identified in several mountain areas, such as the Cajon

Pass, however, just one location was observed below 3,000 ft and only six thermal features containing FAR were documented above 5000 ft.

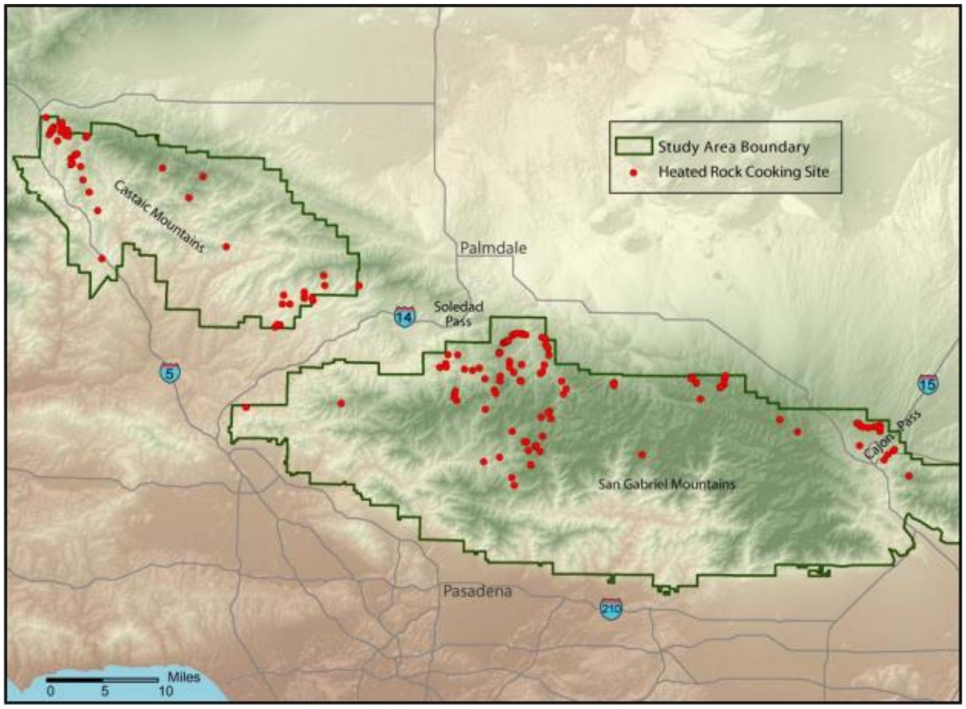



Figure 4. Thermal Feature Distribution, from Milburn (2009)

Various topographic locations within Milburn's study have been shown to yield FAR containing thermal features. These locations include: "valley floors, terraces, saddles, benches, ridgelines," (Milburn *et al*. 2009). The variables that remain similar across the board regarding thermal feature location relate to the leveling of surfaces and are the makeup of the soil and the ability to dig to the desired depth. The most important variable in thermal feature location is its proximity to valued food and fuel resources (King *et al*. 1974:16-17). Milburn points out that yucca appears consistently within the vicinity of thermal features at most locations and elevations (Milburn 2004).

General Thermal Feature Typology

The terminology used to characterize and describe thermal features changes regionally, as well as between archaeological writings. The following list of terms was compiled by Milburn and spans over 30 decades of archaeological writing:  "earth oven,' "pit oven," "stone-lined oven," "slab-lined oven," "grill," "hearth," "central hearth," "rock hearth," "lined hearth," "rock-lined pit," "fire pit," "roasting pit," "roasting platform," "roasting processing station," "processing station," "yucca oven," "yucca roasting oven," "piñon oven," and "burned rock midden," ( Milburn *et al*. 2009:3). Currently, terms such as hearth, thermal feature, and pit have been used locally. Berryman *et al*. (2001:13) acknowledge the difficulty when making regional thermal feature comparisons due to a plethora of terms utilized within literature and local research. Throughout Milburn's writings, he personally refers to thermal features containing FAR as "earth ovens," "grills," and "burnt-rock middens," (Milburn 2006a, 1998, 2004:105-106). Although there are several ways to refer or describe thermal features, there has been no definite regional agreement on terms and characteristics applied to them that is based on archaeological evidence. Regional archaeologists also do not often use the term "hearth" when features are encountered, preferring "thermal feature". The regional use of the term "thermal feature" encompasses a wider range of FAR feature categories including roasting pits, earth ovens, and stone grills (Figures 5, 6, and 8), while “hearth” is a term that applies to a specific typological structure that has yet to receive satisfactory morphological description.

Roasting Pits. A “roasting pit” or “pit” had been used by regional archaeologists as a designation for thermal features whether it be an open-air pit or large agave roasting pit as seen in the Santa Rosa Mountains (McCarthy 2011). Typically, the foods are wrapped in local foliage, then placed in the pit and covered with a layer of soil (Figure 5). Post firing activities include removing the layer of soil to reclaim the foliage packaged food. These features do not include a platform cooking surface (Milburn 2009).

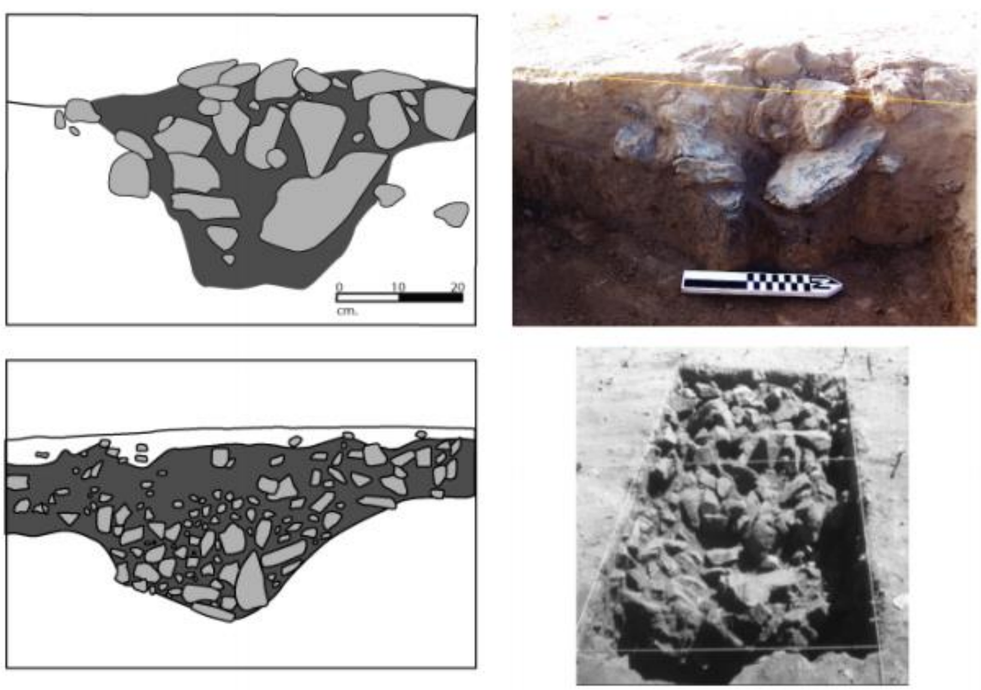



Figure 5. Roasting Pit, from Milburn (2009)

Milburn claims that true roasting pits have not been identified within the Transverse Ranges. While they are not documented in the Transverse Ranges roasting pits are wide-spread throughout the Peninsular Mountain Range, as reported by early 1900's accounts of agave roasting in the Santa Rosa Mountains (Sanders 1923:184-186). Figure 6 shows the locational relationship between the Transverse and Peninsular Mountain ranges.

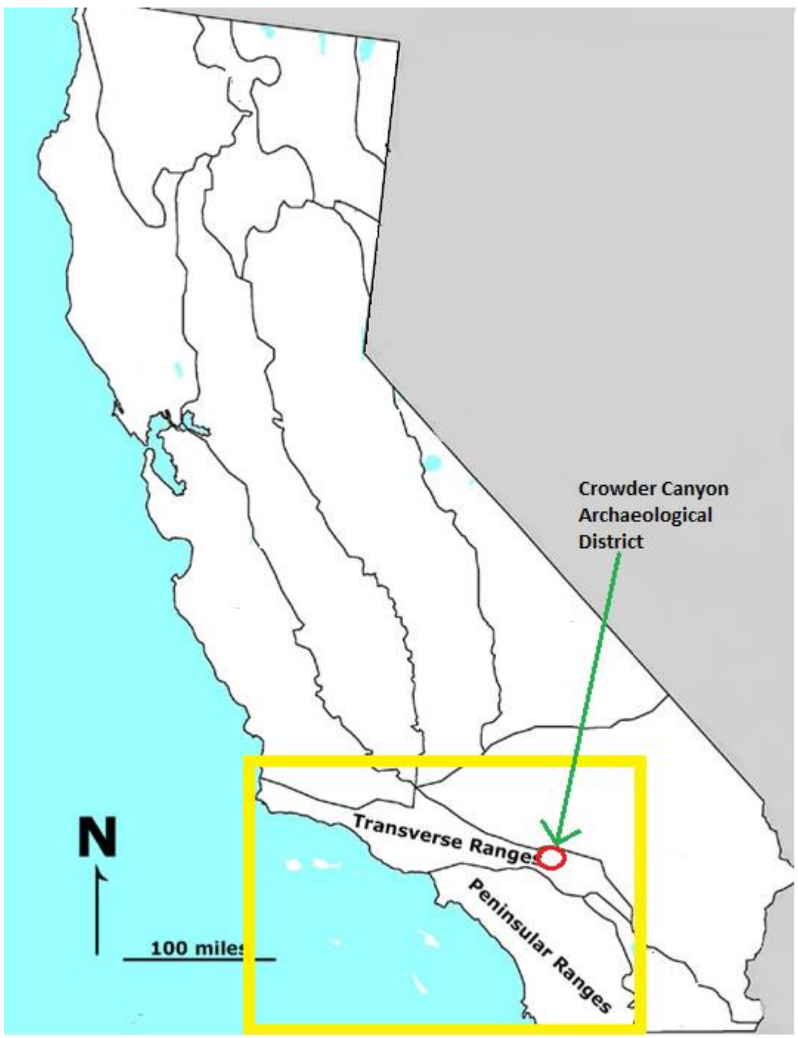



Figure 6. Location of Transverse and Peninsular Mountain Ranges with Regard to the Study Area

Earth Ovens. An earth oven refers to a thermal feature that has a cooking platform, which is then covered with soil, providing indirect heat to the cooked item (Figure 7). The soil placed over the platforms helps to contain ambient heat (Milburn 2004). Milburn has identified and recorded these features in the Transverse Mountain Range (Milburn 1998, 2004, 2005a,2005b, 2006a).

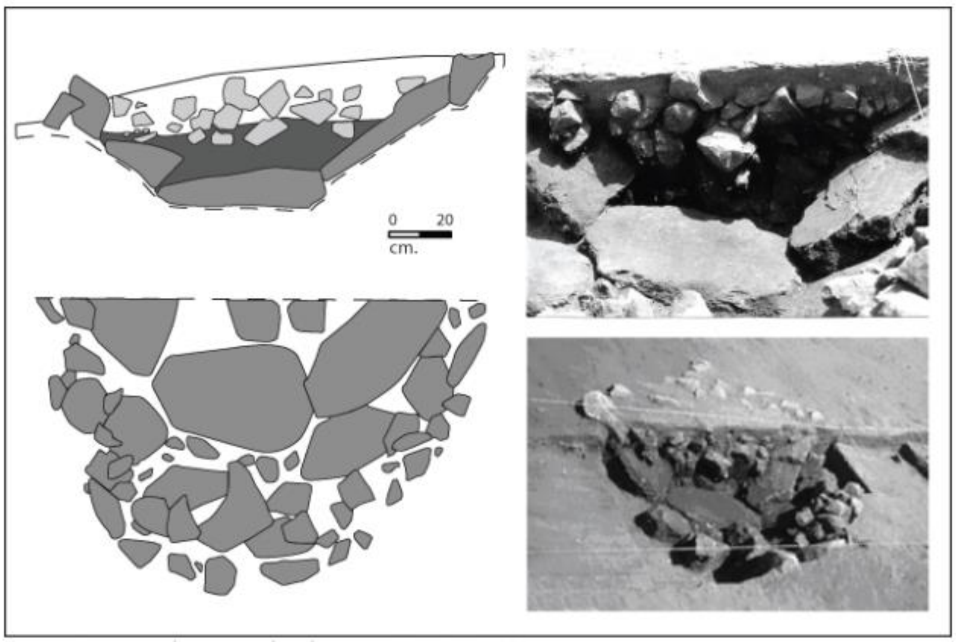



Figure 7. Earth Oven, From Milburn (2009)

Other earth ovens have an ovoid shape and are unlined, like pits mentioned previously, however they have small dugouts removed from the side soil. These feature’s diameters vary from 1.5 meters (m) to 3 m, and their depth ranges from 30 to 100 centimeters (cm) (Milburn 2004:105).

Stone Grills. Grills are similar to pit ovens; however, a grill includes several similar-sized stones placed in a single layer inside of a smaller pit that measures anywhere between 0.5 m and 3.0 m in diameter and has a depth of approximately 40 cm or less (Figure 8). The platform cooking surfaces are not covered by soil as in the earth oven, do not contain a stone liner as some ovens do, and do not retain as much heat as the oven has been proven to do. The grill-type thermal features studied by Milburn were characterized by extremely shallow pits with unlined firing zones (Milburn 2006a).

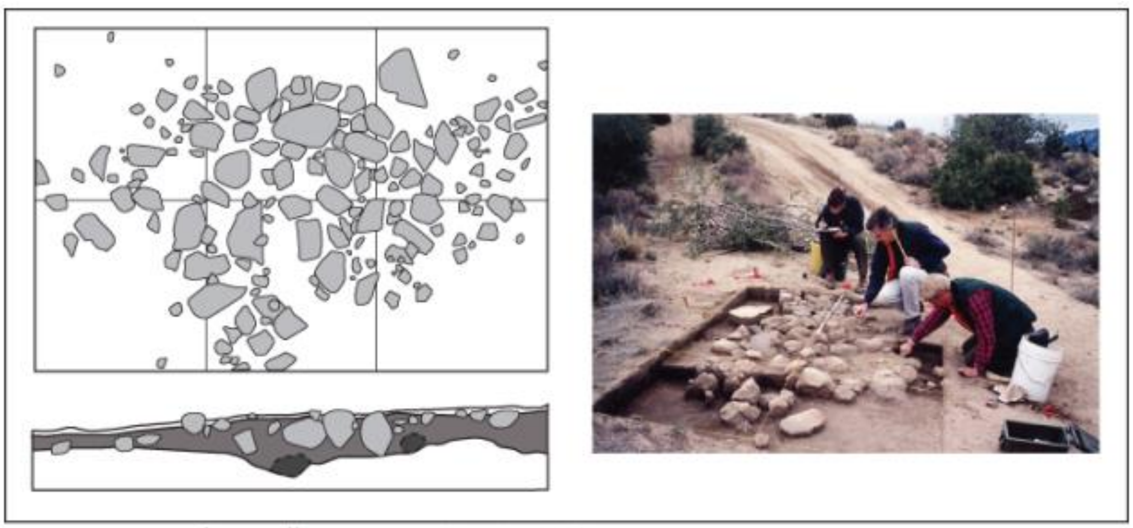


Figure 8. Stone Grill, from Milburn (2009)

The background presented provides regional information regarding thermal feature chronology, location, distribution, terminology, and general typology. All of which were important during my investigation of the study area (Figure 1). A detailed understanding of thermal features and their regional importance facilitated the initial enquiries proposed in later chapters. The foundations of my replicative experimentation and theoretic framework utilize specific information pertaining to thermal feature information and typologies set forth by Milburn's (1998, 2004, 2005a,2005b, 2006a) works, and Thoms' (2009) temporal pattern model respectively.

# CHAPTER FOUR

# THE PHYSICS OF STONES IN THERMAL FEATURES

## Fundamental Thermal Feature Mechanisms

Essentially all thermal features utilized for cooking purposes have two major elements a cooking surface and a fire. If the functionality of these elements is examined closely it can be said that the surface delivers archaeological information regarding the function of the feature. The surface size can indicate what resources were prepared, and how long they were cooked. The third element of functionality is associated stones. The orientation of stone can provide information regarding the degree of use. The feature lining, or lack thereof, can provide information on the amount of heat needed which can also be used to infer resource type (Siegel and Howell 2001). Thermal features can be examined and characterized in various ways through these three elements. It is important to note that these are not the only three elements capable of delivering further information through examination. There are many facets to thermal features, and many ways to approach the study of the features. This may be the reason that only general typologies have been published, like those from Milburn (2009) and Thoms (2009), and why regional archaeologists have yet to agree on a specific morphologic orientation that categorizes these typologies.

The second element mentioned briefly above is the fire itself. The fire can be broken down by its important components (Rehder 2000), the first of which is intensity or temperature. This element of fire essentially determines its capacity to alter plants, rocks, soil, etc. Thermodynamic laws contain the second and third important components of fire. The second component is related to the second law of thermodynamics. This component takes into consideration that heat passes through areas of high temperature to low temperature (Atkins 2010). The third component is considered under the first law of thermodynamics and explains that heat cannot be contained. Essentially, there is nothing in this material world that does not conduct or radiate heat in some form. The moment thermodynamic processes start, heat escapes in all directions into the atmosphere at a constant rate (Rehder 2000; Atkins 2010).

The first component of fire discussed above - temperature and intensity - has an underlying component of its own - duration. These elements ascribed to the first component share a direct relationship with fuel type. The convection process perfectly describes the relationship of fires' three components. As combustion (burning) continues, the intensity of the fire is dependent on the fuel and how it is contained. A small space would create more intense heat, while a larger contained space would radiate less heat into the atmosphere. With these considerations in mind, convection constitutes a continuous loop of thermodynamic energy. Fire burns in its containment, the intensity of the fire causes heat to move from the container to the cooler atmosphere. As heat leaves, the system's oxygen enters the system, thus beginning the cycle again (Siegel and Howell 2001).

The containment of fire is a way to control or direct heat loss due to thermodynamic processes. While the loss of heat is inevitable, fire may be controlled by containment. Ataer (2006:207) states that the "most basic way to contain a fire is to build it in a pit." The main idea behind prehistoric cooking is to essentially generate a large amount of heat quickly, while at the same time producing a way to slow the release of heat in a controlled manner. Stones with dense structures are ideal heat containers. They can store heat and release it slowly over long spans of time depending on their internal structural matrix. However, one caveat exists, the thermodynamic process produces stresses on the stones in the form of expanding and contracting which will eventually degrade the stone (Ataer 2006). We see evidence of this in cases of FCR. This degradation is the main signifier in my research. The degradation or thermal stress of stone due to thermodynamic processes should cause the material to become more porous as it experiences multiple firing episodes which changes its ability to absorb water. The ratio of empty spaces within the stone and the ability to absorb water constitutes the stone's porosity which will be described later (Schalk and Meatte 1993).

Certain variables determine the structural stability of a stone's capacity to withstand thermal stresses. These variables include the stone's size, shape, and rock type (Jackson 1998). Stones of various types - metamorphic, igneous and sedimentary - withstand thermodynamic processed differently; however, prehistoric inhabitants of Crowder Canyon were limited to nearby material.

Resource decisions, in this case stone choice, amount to selecting stones that were in the vicinity and small enough to carry. The type of stone was most likely decided upon by the utilization process. Through use and experience, it was possible for Native peoples to select stones that could withstand multiple firing episodes (Stark 2002). The ethnographic record attributes the use of pits to house the stones, providing a form of insulation that would retain heat (Ellis 1997; Driver and Massy 1957). This type of thermal feature orientation is the basis of my research. Theoretically, this type of feature suggests intensification of food preparation and a shift in dietary resources (Thoms 2009).

Cooking technologies changed over time throughout the archaeological record, as shown by Thoms (2009). The thermodynamic properties of stones are important for facilitating various prehistoric cooking technologies across every continent. Ethnographic documentation suggests the most prevalent form of thermal feature containing stones are pit-type features (Driver and Massy 1957:227–230; Nelson 2010).

## Porosity as a Measurement of Firing

The phrase and song lyrics “solid as a rock” may need an overhaul. As this research has shown, stones are not the solid mass one might expect. Stones, whether they be of metamorphic, igneous, or sedimentary, have matrices with tiny pores. These tiny pores trap oxygen (Science Budies 2012) and the various types of stones each have their own measurable capacity to store oxygen and water. When the discussion turns to water absorption the discussion of porosity begins. The more pores a stone has the larger amount of water it can absorb. Stones with more pores or larger pores than others are said to be less dense than stones with fewer or smaller pores, thus porosity is directly related to the density of a given stone (Manger 1963:3-4). In the same vein, more pores are equivalent to higher porosity. Density is a property of stone; therefore, we can extrapolate the idea that porosity can also detail differences between stones.

As mentioned in previous sections, a stone's matrix determines its capacity to withstand thermal stresses. The matrix is comprised of very small particles that are tightly packed with intermittent air pockets throughout. Tightly packed particles have several correlates; first, the stone is less porous; second, the stone is denser; third, the stone can withstand more thermal stresses; and fourth, the stone can retain more heat (Manger 1963; Rehder 2000; Atkins 2010). This project constitutes an examination into the porosity of schist stones and how that porosity changes due to thermal stresses. The thermal stresses are presented in the form of the episodic firing of the stones within grills comparable to prehistoric examples constructed for the purposes of evaluating cultural material collected from the Crowder Canyon study area. The ability of the stone to store water is important in this examination as it is this ability that will be used to measure the changes in the stone's structural matrices. A stone's ability to store water can be determined by the ratio between its total volume and its pore volume (Yavuz *et al*. 2010; Manger 1963:45).

Theoretically, a stone's porosity will increase as the stone degrades due to thermal pressures (Somerton 1992:6). In theory, this increased porosity should provide some data on a heated vs. a non-heated rock of the same type. That is the basis for the experimentation in this project, which required a baseline of absorption that was established for a control group of non-fired rock. Then subsequent absorption values for stones that had been fired 1, 3, 5, and 7 times were tested for absorption values. Because absorption is a function of porosity, this project directly calculates porosity with respect to a stone's capacity to absorb water in pre-firing and various post-firing conditions.

This information poses several lines of questions that can be answered through experimentation: Does a stone's porosity change with firing? How does a stone's porosity change with multiple firings? This line of questioning can be answered theoretically, but the replicative experiment provides support to the theoretical approaches when answering these questions. Should these questions be answered and supported by this research then future considerations can be made for further research when determining ecological factors associated with the reuse of thermal features.

# CHAPTER FIVE

# THEORETICAL FRAMEWORK

## Human Behavioral Ecology and Optimal Foraging Theory

Human behavioral ecology (HBE) can be utilized in this examination as the study of human behavioral choices and activities that facilitate processes of adaptation and change due to ecological pressures (West and Burton-Chellew 2013). Ecological pressures, such as the changing availability of resources, increasing population sizes, and changes in climate conditions, can cause varying choices pertaining to mobility patterns, seasonal rounds, and resource procurement. When processes of behavioral change across spaces and time are examined within a cultural tradition or across cultural traditions, it is obvious that the nature of these systems is extremely fluid.

In theory, if the process of behavioral change is considered fluid and ever-changing due to ecological stresses, then it makes sense to extrapolate that idea to ecological stresses itself. By this I mean the entire system of behavioral changes and ecological stresses share a relationship with ebbs and flows. They both act on each other. For example, when a population increases due to plentiful resource availability, the ecological effect to the environment could be resource intensification that could later lead to depletion of resources and thus the population would have to utilize movement, a behavioral change, to acquire new resources.

Optimal Foraging Theory (OFT) can demonstrate a fundamental understanding of behavioral ecology within my study region and the need to survive efficiently on available resources. Through my analysis of regional FAR and future research considerations outlined in this section, it should be possible to present a coherent and multifaceted inference on the phenomena of prehistoric site use and reuse.

Inferences on the analytical capabilities of FAR were derived from data produced by this research and considered using an OFT framework with respect to settlement location and subsistence strategies. OFT directly involves foraging theories, and these theories are based on the decisions of foragers which are ultimately influenced by natural selection (Smith 1982). This means that foragers will select locations and patterns of mobility that will maximize population efficiency, in terms of foraging time, resource processing, and movement (Smith 1983). The locational and seasonal availability of resources, in particular, yucca, can be correlated with decisions regarding patterns of mobility of groups across particular landscapes.

The choice of processing yucca using manzanita fuel and the procurement of schist stones can also be considered using OFT. Under this theoretical approach, foraging decisions are made to maximize the net rate of return. The choice of resource, yucca, and fuel choice of manzanita have been identified in previous studies as the main plant resources utilized in the area (Milburn 1998). Previous excavations conducted in the research area included microbotanical analysis that identified traces of these resources within subsurface thermal features (Milburn 2009). Additionally, ethnographic studies suggest that the prehistoric Serrano who occupied the region were organized into a logistical settlement pattern (Bean and Saudel 1972). The shift in diet when occupying upland desert regions essentially means a shift into more fibrous resources that need further processing which costs more in terms of calories and time to process. Thus, choices need to be made concerning efficiency in the processing of acquired fibrous resources.

As OFT decisions are made, such as the choice of yucca as a food source and manufacturing material, more efficient means of processing must take place. In this case, the fibrous yucca needs longer processing times, so it makes sense that Thoms' (2009) model, depicts changes in thermal feature morphology and efficiency over time (see Figure 3). This model supplies an overview of the changes in thermal features as time moves forward and as various resources requiring more cooking time are utilized. Thoms' model also incorporates HBE and posits that behavioral changes can be monitored by looking at the changes and placement of thermal features across the landscape. For example, he notes that higher frequencies of features imply shifts to more plant-based processing and indicate population growth, possibly due to the availability of a chosen resource. These are all behavioral shifts that can be detected over time.

The theoretical approaches I have outlined regarding OFT can provide data on foraging strategies, resource availability, seasonality, and resource choice within a given area. The stone grills considered in this project are prominent features within archaeological sites in this region. A plethora of these features were reused through time (Milburn 1998), as the stones selected to build the prehistoric grills are typically chosen to withstand multiple uses. The reasons for the reuse of these sites can be explored using an HBE approach. Future considerations include behavioral choices across the landscape and over time, specifically regarding resources deemed significant for survival. Essentially, the availability of significant resources in each area drive the inhabitant's decision-making processes. FAR and its analytical properties can be used to inform on these processes, specifically as they pertain to site use, reuse, and mobility patterns. Considering data from absorption rates along with knowledge of resource availability and AMS dating of associated charcoal can provide information regarding site reuse and information regarding firing episodes. Theoretically, these data can be used to understand mobility patterns, site use, and subsistence strategies.

Reoccurring Site Occupation

In my area of interest, a choice was made by prehistoric peoples to utilize yucca and manzanita as resources during occupation. The availability of yucca and manzanita is directly reflected in the occupants foraging strategy according to previous research and ethnographic accounts for the area (Bean *et al*. 1972; Basgall and True 1985). The choice of local yucca in terms of food resource and choice of local manzanita in terms of fuel resource regarding processing time is ideal when focusing on maximum net return. Examination within the broader scope of HBE regarding my research recognizes the change of thermal features throughout the archaeological timeline as an adaptive strategy, as shown in Figure 3.

# CHAPTER SIX

# METHODS

Stone porosity was determined by calculating the stone's ability to store water. The derivation of the equations used is based on the bulk volume of the stones (dry weight of the stone) and the total porosity of the stone (ratio of bulk volume to total pore volume) (Yavuz *et al*. 2010; Manger 1963:45). The methods utilized to find bulk volume and total pore volume of both the experimental materials and cultural materials, as well as the calculations performed, are detailed in the calculations sections below.

The comprehensive values for absorption and porosity from the controlled experiment were analyzed against the average porosity value of the cultural samples collected from archaeological thermal features located in Crowder Canyon. This comparison allowed the determination of the number of times the archaeological samples had been fired. This type of absorption data may be used in conjunction with AMS dating to help identify episodic reuse of site and possibly habitation intensity at individual sites at specific intervals in time. Previous research has shown that repeated firings of stones over time indicate multiple repeated site use and occupations (Eddy and Garfinkel 2009).

## Geological Referencing and Sourcing of Schist

The replicative experiment required the recovery of several schist stones which match the cultural material in approximate size. The non-cultural schist was collected from a large wash located in the Crowder Canyon Archaeological District (Figure 9). The cultural material analyzed in this project is local to the Cajon pass and originates from the same formation as the non-cultural material that was used during the experimental firing phase. This section will detail the formation of schist and its prevalence throughout the study area.

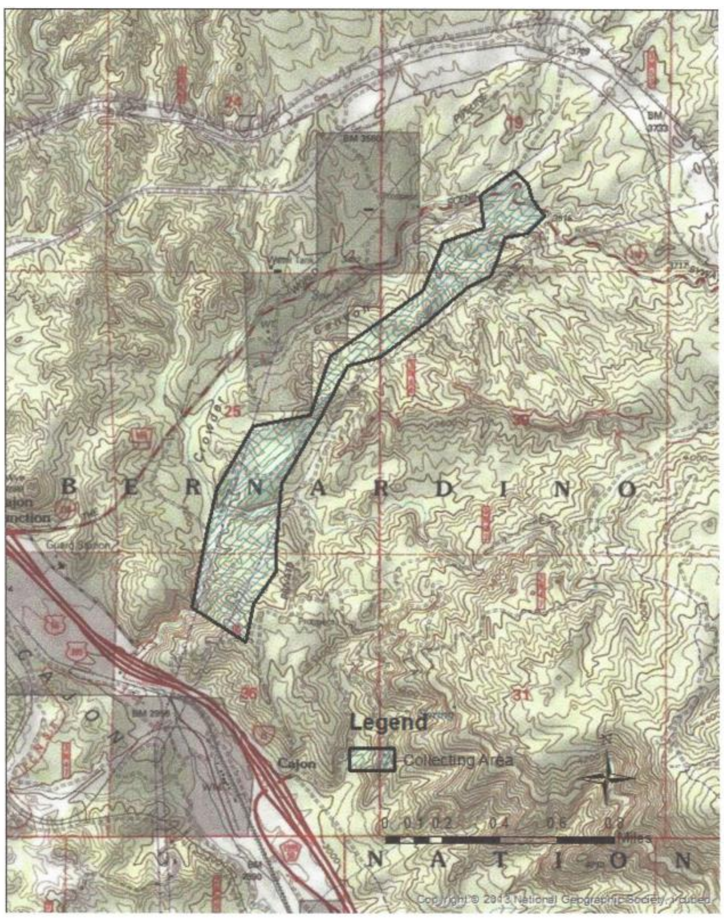



Figure 9. Non-Cultural Collection Area in Crowder Canyon

This specific formation of schist within the study area is considered by most geologists to have formed in the Mesozoic Era, which means in terms of geological time, the formation is approximately 66 to 252 million years old. The most notable natural feature within the Cajon Pass is the San Andreas Fault (Figure 10). It stands as the largest fault across California and causes the most seismic activity in Southern California. The fault orients itself through the "Pass" and separates the Pacific Plate and the North American Plate (Bandringa 2009). The Cajon Pass was originally created when the Pacific and North American Plate collided then separated millions of years ago, with stable water sources carving out a canyon through several millennia.

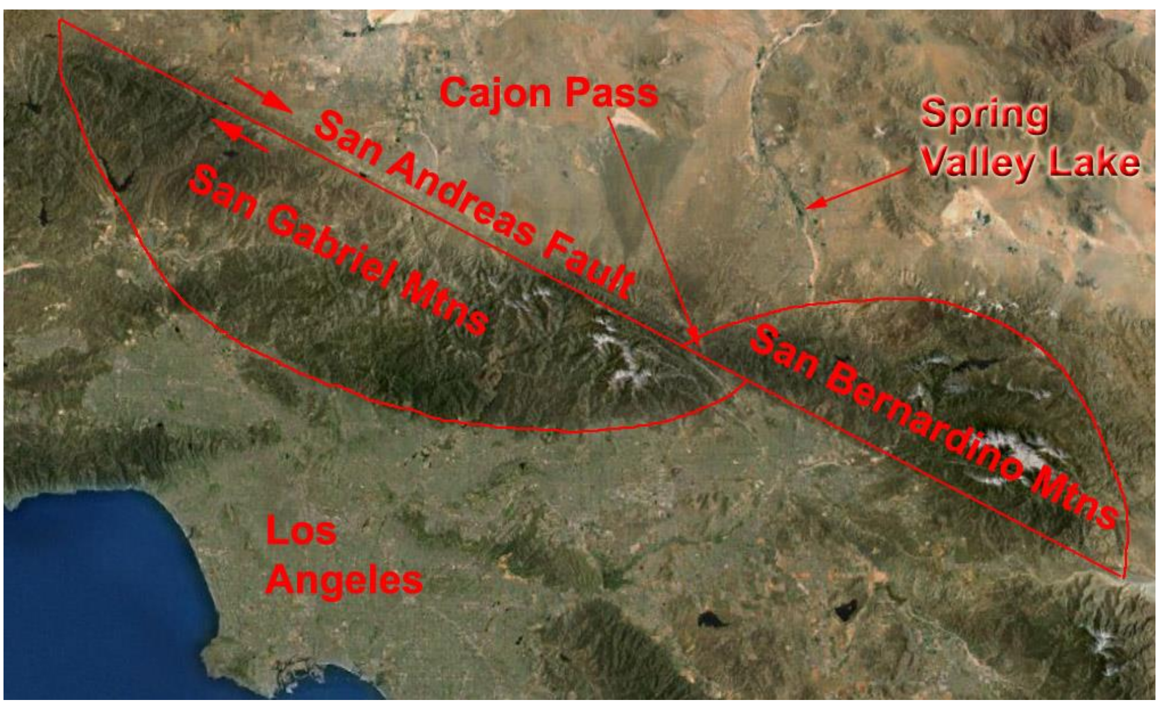


Figure 10. Satellite Image: San Andreas Fault, from Back Road West (2011)

The San Andreas fault's seismic activities have pushed lower plate rock and lower amphibolite to the surface. Both sections of stone include outcrops of schist-granitic stones. The thick green schist, locally called Blue Cut Schist, and metamorphic grade schist, locally called Pelona Schist, are the types of schist native to the area of The Cajon Pass. (Morton 2000).

## Collection of Non-Cultural Material

The non-cultural material collected for this experimentation was Pelona Schist found in in Crowder Canyon where it erodes out of the canyon walls (see Figure 2). The cultural collection area depicted in Figure 1 is located just north of the lower plate of the Vincent Thrust, which produces Pelona Schist (Figure 11). Pelona Schist was identified within the prehistoric thermal feature excavated in Crowder Canyon. To replicate the cultural firing as closely as possible, Pelona Schist was desired for experimentation. It was located and collected from the non-cultural collection area depicted in Figure 9, and utilized for the experimental firings. A permit issued by the Lytle Creek Ranger Station permitted the collection of Pelona Schist stones from the non-cultural collection area. After the permit was issued, 40 stones of similar size and weight to the cultural material, were collected from the canyon walls within the collection area.

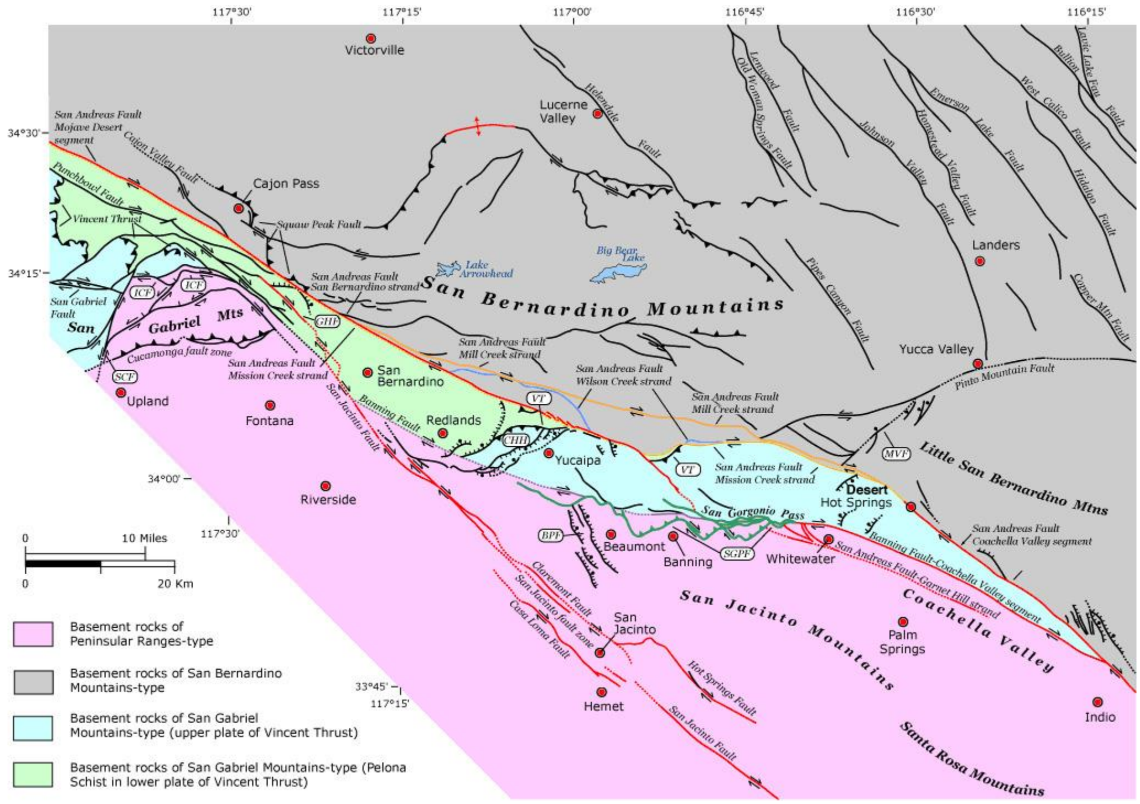



Figure 11. San Andreas Fault Zone, San Bernardino Mountains Segment, from United States Geological Survey (2004)

## Collection of Cultural Material

The cultural material was collected in tandem with an excavation contracted by the U.S.D.A. Forest Service (USFS) and conducted by Applied Earthworks. The project constitutes one of the few projects conducted in the Crowder Canyon Archaeological District as stated previously in this paper. Initially, the project began as a form of mitigation that intended to salvage information from subsurface cultural deposits from an area of potential effect, outlined in a road widening project proposed by California Department of Transportation (Caltrans). As an intern with the USFS, I was given entry into site

CA-SBR-3773, and was granted permission by USFS and San Manuel Band of Mission Indians (SMBMI), to remove a portion of a stone grill from a thermal feature located within the site. While I was not involved in the excavation of the stone grill, the field technicians placed a portion of the cooking platform, consisting of 13 samples of FAR, aside in preparation for my investigation.

SMBMI requested repatriation of the excavated material; however, they granted the collection of a portion of the material under the USFS permit issued to Applied Earthworks. The collected FAR comprised random portions of the cooking platform, from the thermal feature located five meters from the open road that was to be widened. This thermal feature is a single-course rock grilling platform with a general typology similar to the descriptions provided by Milburn's previous typology regarding stone grills (Figures 8 and 12). The thermal feature excavation was underway at the time of collection, with analysis, complete typology including depth measurements, unavailable at the time of drafting and editing this thesis. As such, Milburn's 2009 previous descriptions of thermal features associated with the study area was utilized analogously during this research.

Figure 12. Stone Grill from which Cultural Material was Collected

## Mathematical Formulations

### Cultural Porosity

The post-firing porosity of the cultural material was calculated for each stone by first determining the pore volume of the stone. To find the poor volume of the stone, the difference in saturated weight and dry weight was recorded in grams. This follows the ratio explanation earlier stating that porosity is equal to the ratio of the stone’s empty space volume to its total volume. Because the ratio of grams to milliliters (ml) is 1:1, grams was easily converted to ml. Next, the total volume of the stone was calculated by measuring the amount of displaced fluid after submersion of the stone. It is important to note that during initial submersion the stone began to bubble, taking on characteristics of an alka seltzer tablet (Figure 13), as the spaces in between the stones structural matrix were filled with air. As the stone is submerged into the fluid, the air or any other gases in those spaces are displaced by the fluid and begin to escape into the atmosphere which causes the "fizzing" activity. The fizzing activity subsided approximately an hour after submersion. At that point, I determined this to be the max resting porosity (Figure 14).


Figure 13. Initial Submersion


Figure 14. Max Resting Porosity

The final step in calculating total porosity of the object was to assign the values for pore volume and total volume into the porosity equation:

Porosity ($P_t$) $= \frac{Vp}{Vt} x\ 100 = \frac{Total\ Pore\ volume}{Total\ object\ volume} x\ 100$; (Gane *et al*. 2004)

Pore Volume ($V_p$) =Saturated weight - Dry weight

Total Volume ($V_t$) = Volume of Displaced Water.

The total was then multiplied by 100 to provide a porosity percentage after firing.

This process was completed once per cultural stone. In total, I ended the calculations with 13 porosity percentage values, which were then combined as an average porosity value for collected cultural material. The following sample calculation was completed using the saturated weights, dry weights, and fluid displacement for the cultural material collected from the stone grill depicted in Figure 12.

Example 1:

1088.97g-1088.62g x (1$mL$/1$g$) = 0.35mL= ($V_p$) Pore volume

2855mL-2500mL= 355mL= ($V_t$) Total volume

(0.35/355) x 100 = 0.0986% ($P_t$) Porosity

The average porosity was calculated for the cultural material which includes all 13 cultural stones collected from the prehistoric feature. The Average ($P_t$) = **0.138%,** will be utilized later in the *Results* chapter.

Once the porosity for the cultural stones was determined, I could then use this for a comparison for the non-cultural stones that I fired a varying number of times. To acquire comparative data for the non-cultural stones, I needed to determine the porosity of the stone material before it was fired.

Non-cultural Porosity

The porosity for the non-cultural material was determined eight times, which represents each of the four firing groups. Group 1 represents material fired once. Group 2 represents material fired three times. Group 3 represents material fired five times. Group 4 represents material fired seven times. The difference between the pre- and post-fire porosity of these stones was determined. From these data, it was possible to plot the porosity values against the number of firings in a graph. The graph was used to create a trend line which formulated an equation to best fit the 10 data points recorded during experimentation. The formula generated from the graph, presents the direct relationship between porosity and number of firings. Utilizing this relationship, it was possible to solve for the missing variable, in this case the number of firings. Essentially the replicative experimentation allowed me to create an equation in order to calculate the number of times the cultural stones were fired, based on their porosity values.

## Replicating Prehistoric Cooking Features

The regional replicative study found in McCarthy's (2011) reconnaissance report, provide cooking times for certain plant parts as they pertain to thermal feature characteristics. This replicative information details the cooking times for specific portions of agave and yucca including: the heart, stalk, blossoms, fruit pods, and seeds, and offers examples of what kind of morphology of thermal features would be ideal when cooking each portion. These cooking times were used as a baseline for yucca cooking times in this project (Table 1).

Table 1. Experimental Yucca schidigera Cooking Times per Plant Portion, from McCarthy (2017)

| Plant Part | Type of Thermal Feature Used | Approximate Cooking Time |
|---|---|---|
| Heart | Roasting Pit | 30 to 40 Hours |
| Young Stalk | Hearth or Grill | 60 Minutes |
| Blossom | Eaten fresh/parboiled in ceramic vessel | Several Minutes |
| Fruit Pod | Baked in small, rock lined oven/roasted directly over coals | 20 to 35 Minutes |
| Seed | Ground to a four and added to soups or stews | 15 Minutes |

The thermal features outlined in McCarthy's (2011) previous agave and yucca replicative study incorporated stones that were determined to be grills and roasting pits based on the size and orientation of FAR within the features; however, clear standardized categories and characteristics have yet to be determined in California (McCarthy 2011). At time of this investigation, Milburn's 2009 thermal feature typology stands as the most complete list of characteristics in the region of study and currently stands as the foundation of my research.

Grilling Platforms

Grilling platforms are composed of several similar sized schisty-granitc stones (Figures 15 and 16) placed single-course in a shallow depression in the soil. The single-course placement of the stones, within the depression, creates a cooking platform. Yucca stalks were laid across the platform and the fuel placed on top. In some cases, fill, constituting smaller stones, were place on the fuel layer to retain more heat, otherwise the resource was prepared as described.

Figure 15. Unfired Non-Cultural Material.

Figure 16. Cultural Material: Examples 1 and 2.

Fuel

The fuel was sourced from the same area as the cultural material. Millburn's 2009 work previously explained that micro-botanical analysis completed for previously analyzed thermal features resulted in identification of manzanita as the local fuel source. I received approval from Caltrans to collect several hundred pounds of manzanita that had been cut as part of a development project, and was slated to be discarded. Once the manzanita was uprooted by Caltrans, I was escorted onto the property to remove the material that I needed. This material was then taken to the location for the firing experiment in Lucerne Valley. Approximately 60 lbs. of the manzanita were used in a preliminary and replicative experimentation, which will be explained in further detail below.

Experimental Firing of Non-Cultural Material

As mentioned above, small wood fires typically reach temperatures of well over 500°F and the typical modern barbecue cooking temperatures can reach well over 700°F. Considering this variation preliminary experimentation was conducted to determine a controllable temperature range, which was identified at 600-700°F. Because manzanita is an extremely efficient fuel source that burns longer and hotter than other woody material present in the study area, the wide temperature range reported allowed temperature maintenance during the replicative experimentations. The temperature was maintained using an infrared thermometer gun, along with the addition of fill where needed. Cooking times were determined following McCarthy's (2011) experimentation. The FAR collected from the study area was determined by Milburn's (2009) typology to be a stone grill (Figures 8 and 12), and based on McCarthy's experimentation yucca stalk was cooked in stone grills for 60 minutes (Table 1). The presence of yucca identified in thermal features within the study area, presented by Milburn (2009), further supports this method of approach. A cooling period of 3 hours was determined by the average time the stones temperature changed from post firing temperature (after one hour of cooking time) to pre-fired-resting temperature.

The experimental firing groups below were all fired between 600-700°F for 60 minutes, and allowed to cool for three hours. These experimental parameters were based on the analogous information provided by Milburn (2009), McCarthy

(2011) and preliminary experimentation as described above. Groups Two through Four including cooling periods of three hours between firings.

Firing Group One. This group of two stones was fired one time and the temperature and the porosity was calculated for each stone.

Firing Group Two. This group of two stones was fired three times and the final porosity was calculated for each stone.

Firing Group Three. This group of two stones was fired five times and the final porosity was calculated for each stone.

Firing Group Four. This group of two stones was fired seven times and the final porosity was calculated for each stone.

The final porosity values for each of these non-cultural stones were then used as a baseline for comparison with the porosity values of the cultural FAR to determine approximate porosity values that can indicate number of firing.

## Implementation of Design and Function

I made several typology adjustments regarding the grill for this research. First, I needed to scale down the experiment. I was unable at the allotted time to procure all materials needed for large-scale experimentation and manzanita in bulk is extremely hard to come by because this particular species is protected in the study area. For this reason, it was prudent to initiate small scale experimentation by only utilizing 10 sample stones in total. The results represent a small facet of the investigation into the utility of FAR. These stones were fired in a controlled environment (e.g. modern grill) with every other variable including the fuel, temperature, and cooking times consistent with known prehistoric examples.

# CHAPTER SEVEN

# RESULTS

The results shown below in Table 2 represent the various firing groups from zero to seven individual firing episodes and their corresponding experimental porosity percentages. These figures were placed into a histogram (Figure 17) to define a pattern. An equation was generated from the data points, which was then applied to the cultural material to formulate an approximate number of firings for the entire prehistoric stone grill. It is important to note that the following results are based on a sample of the cultural material and small-scale experimental firings of the non-cultural material. While the data presented in this section is precise with regard to the small-scale experimental parameters, the limitations of the replicative experiments and results are discussed below in the *Limitations and Further Considerations* section, as well as the *Discussion* section.

Table 2. Porosity Results per Number of Firings

| # of Firings | Sample 1 | Sample 2 |
|---|---|---|
| 0 | 0.0527 | 0.0499 |
| 1 | 0.0549 | 0.0668 |
| 3 | 0.0622 | 0.0598 |
| 5 | 0.0794 | 0.0802 |
| 7 | 0.0889 | 0.0796 |

Figure 17 shows the linear relationship between the data points, from which an equation can be generated. If the known value of the cultural stone grilling platform average porosity is ($P_t$) = 0.138% as described in the Mathematical Formulations section of Chapter 5, then solving for X provides the missing variable of the generated equation. The data range between 0.057% - 0.308% porosity. The standard deviation (σ)= 0.079 for the 13 cultural porosity values. All porosity values fall between ± 1σ (0.059% - 0.217%) accept one data point, 0.308, constituting a numerically distant value; however, this value falls within 3σ of the average, and is still considered within normal distribution range. The equation formulated from Figure 17 below provides the missing variable: X= (Number of firings):

Where X= Number of firings, and Y = Porosity (%)

$y = 0.0039x + 0.0547$

$0.138 = 0.0039x + 0.0547$

$0.138 - 0.0547 = 0.0039x$

$$\frac{0.138 - 0.0547}{0.0039} = \frac{0.0039x}{0.0039}$$

$$X = \frac{0.138 - 0.0547}{0.0039}$$

X = 21.26 firings; because there is no such thing as partial firing, this number will be rounded up to the nearest firing, i.e. 22. On average this collection of cultural material was fired approximately 22 times. This extrapolation of the data is only based on the limited experimentation conducted and represents the extrapolation of inferred information possible if the line of regression for further firings, remains consistent with this research. However, is safe to state, categorically, that based on the information provided by the small-scale experimentation and equation from Figure 17, the cultural material was fired no less than seven times. This suggests that the stones from the grill were reused many times and can provide additional data with which to determine site use and reuse patterns.

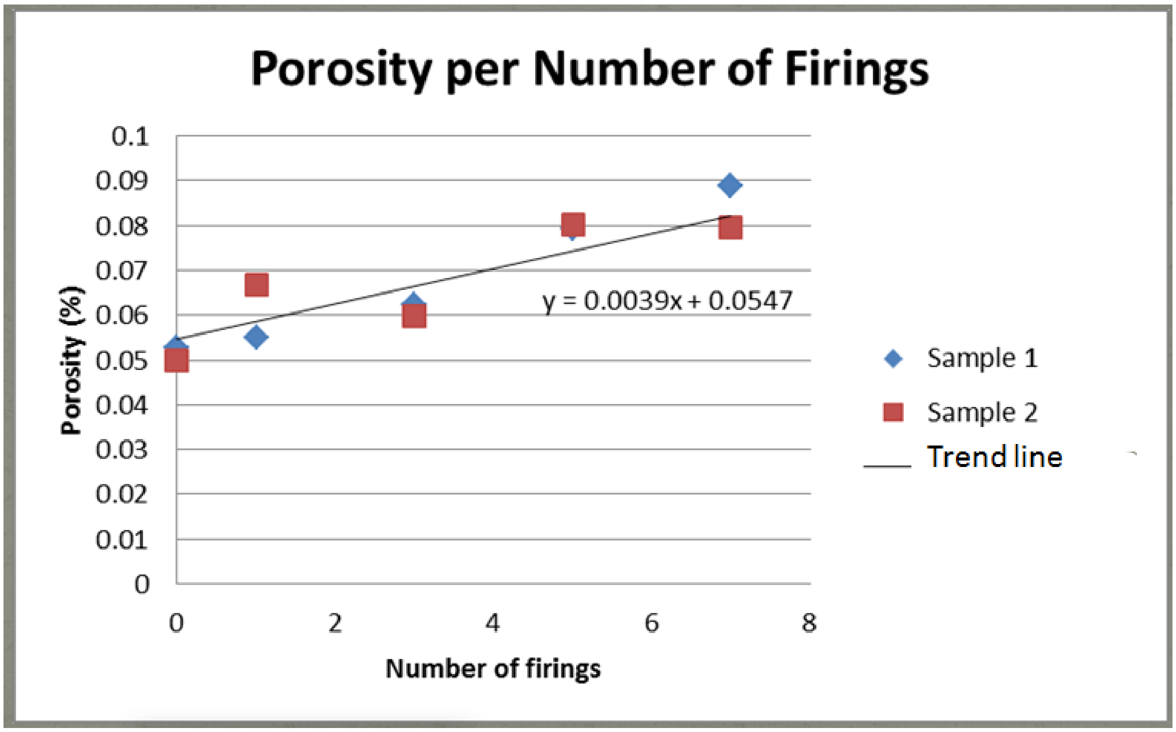


Figure 17. Porosity per Number of Firings

Limitations and Further Considerations

I considered limitations throughout this experiment, in particular, the fact that my analysis as it stands can only determine the probable number of firings within a habitation episode. Alone it does not determine site reuse over long chronologic periods of repeat occupation; this specific information can be inferred through carbon AMS dating and the identification of associated cultural material. If carbon samples are collected and tested in a unit with FAR and multiple date ranges are identified then we can infer that the thermal feature was utilized several times over a span of time (Milburn 2011). AMS dates, from charcoal collected *in situ*, that return with one associated date will confirm that the feature was used multiple times during one episodic occupation. While this method of FAR analysis is valuable when no other associated artifacts are identified and as an identifier of multiple firings per feature, it is important to note that chronological occupation over vast periods of time will need to be confirmed using multiple variables.

My technique has answered, although not categorically nor equivocally, the enquiries posed in Chapter 3, which questions the change in porosity due to firing. Tentatively, the answer to this question is yes. Based on my experimentation, porosity does change with firing, and it continues to change as the stones experience multiple firings as shown in Table 2 and Figure 17 of the results section. It is important to note that my replicative experiments contain some shortcomings and further consideration, which are discussed below.

Upper Firing Limit

There were a limited number of firings conducted that do not account for an upper firing limit. The upper firing limit provides a concrete range of change in porosity the stones experience over repeated firings. It is possible that the upper firing limit will provide insight into the maximum number of firings a stone can withstand, and what happens to a stone physically as it reaches its maximum firing limit. These physical changes may account for discarded FCR identified in the archaeological record.

Ethnographic documentation details situations where overtly damaged stones were thrown out and replaced by new ones. These overtly damaged stones may be the origination of the FCR mentioned earlier. The FCR may represent an upper firing limit. There was no FCR visible during the excavation of the thermal feature at Crowder Canyon, so no FCR was obtained for this analysis. If FCR indicates an upper firing limit, this would help to create a gradient of porosity and physical characteristics that may aid in the determination of repeat use without laboratory analysis. By this I mean that it may be possible to determine the number of firings based on the presence of FCR, however; further investigation is warranted in this case.

Small-scale Experimentation

The presented data (Table 2, Figure 17) provides a linear function and it is possible that future firings can uncover an exponential relationship between porosity and the number of firings. Figure 17 depicts the results of the experimental firings. There is a clear linear relationship between porosity and the number of firings experienced by the stones. The small-scale replicative experimentation supports the theoretical information in Chapter 3. Porosity does increase as the number of firings increase according to the limited experimentation; however, porosity may decrease as the stones are continuously fired beyond that of the small-scale replicative experiment conducted for this research.

## Considering Further Optimal Foraging Theories and Human Behavioral Ecological Approaches

The facet of OFT that can be utilized in future investigations ascribes importance to foraging strategies regarding yucca and manzanita. Yucca constitutes a main plant food source for the Cahuilla (Barrows 1900; Bean and Saudel 1972; Bean et. al. 1991). Although yucca heart harvesting is seasonal, portions of the plant are available for consumption all year round (McCarthy 2011). Manzanita has been found to be the primary source of fuel as it is readily available in the area and is extremely efficient, burning at higher temperatures and for longer periods of time than any other available fuel source (Milburn 1998). These two important resources are very abundant on the ridges surrounding Crowder Canyon.

Future research can consider multiple variables of adaptive choice and efficiency strategies and correlate these choices with site reuse using FAR analysis. By considering the choice of yucca and manzanita as beneficial to the fitness of the individual using OFT, it is possible to correlate this benefit to a settlement pattern that maximizes procurement of these two important resources. However, while individual fitness is essential, it may not always be the driving factor in group decisions such as settlement and site reuse. Incorporating an HBE theoretical perspective allows insight into the decisions of occupying groups over a temporal span, thus facilitating a diverse line of questioning for a future project.

Considering Carbon Staining of Stones and Soil

While conducting the experimental firings it was observed that both the stones and surrounding soil were left with carbon staining. This staining may be useful in inferring the number of firings a feature has experienced when fully analyzed over a long span of time experimentally. Further investigation into this observation may provide a glimpse into the archaeological signature a thermal feature may leave behind. This firing signature may be used to distinguish between single-use and multi-use as well if the staining is the result of a non-cultural fire. Although it may be argued that this type of carbon staining will not survive in the archaeological record, it is my experience that on the occasion when a thermal feature is identified within its original context, (i.e. backfilled after final use), there is a staining that occurs on both the stones and the surrounding soil, that is preserved and can be identified archaeologically, as seen in Figure 18.

Figure 18.My 2015 Excavated Thermal Feature with Stained Soil

# CHAPTER EIGHT

# DISCUSSION

Thermal features, especially those utilized for cooking during prehistoric periods of occupation in Crowder Canyon, are encountered at almost every site in upland desert regions of southern California and many regions around the world. Yet these features have had little attention paid to them with limited archaeological analysis performed on them, when compared to other archaeological material and features. If they are encountered and recorded, the terminology used to categorize them is often vague and non-descriptive. This is likely because thermal features rarely have the preservation or associated material that provides data to assist in the determination of their function. Certain types of specialized analysis, such as microbotanical analysis, can sometimes provide data on the types of food processed or fuel used in the grill; however, beyond generalized assumptions, i.e. cooking and heating, it can be difficult to interpret a thermal feature beyond a vaguely assumed processing of food by fire (Milburn 1998). While this is an important base-line assumption that provides subsistence data, FAR may be able to add to our understanding of the episodic site use of prehistoric people.

When an entire thermal feature is examined from a multifaceted perspective, including the analysis presented in this thesis, FAR's utility becomes more apparent. This thesis has presented a method to gain information from the oft discarded artifact. The typical analysis of the FAR from thermal features consists of weighing and possibly counting, and then discarding the stones. This process negates these important site constituents and does not consider that the FAR itself may contain a reservoir of valuable information. As discussed in my theoretical framework I consider a fundamental understanding of HBE and the need to survive efficiently. By conducting my replicative experiment, I have produced a way to test the analytical capabilities of FAR adding another analytical capability to explore and infer patterns of mobility and subsistence choices. As such, episodic habitation can be investigated based on the analysis of FAR. This information along with AMS dates, Thoms' (2009) basic temporal model of cooking facilities that connect adaptive efficiency (HBE) and procuration strategies (OFT) can cultivate a more detailed understanding of strategic subsistence choices in the study area and similar areas in southern California.

## Fire-Affected Rock Analysis in Action

Archaeological visibility is very important. If an artifact cannot be seen, it cannot be considered in the archaeological record. As an example, the feature shown in Figure 19 was identified in Baldy Mesa, an area adjacent to the Crowder canyon district. It was recorded as a probable thermal feature but it was never determined if the feature was prehistoric, modern, or even if it was indeed cultural. With my proposed analytical process, it would be possible to determine if it was a naturally occurring feature due to a passing fire, a prehistoric feature utilized a multitude of times, or if it was a single use modern campsite.

Figure 19. Baldy Mesa Thermal Feature

A natural occurring feature that has been deposited due to a passing fire will have associated FAR that will be in a more dispersed pattern than the tighter intact deposits identified as archaeological thermal features. These dispersed natural occurring deposits can also be mistaken as middens at the surface. However, middens have depth, a distinct greasy slip about them, as well as associated archaeological debris such as faunal remains and other associated artifacts (Schneider *et al*. 1996; Thoms 2009; Yavuz *et al*. 2010).

My method of analysis not only sheds light on the change in porosity values for stone fired *x* number of times, but I also observed what I might call an archaeological imprint left at the completion of *x* number of firings, which I discussed briefly in the *Limitations and Further Considerations* section of this thesis.

This analysis provided more information regarding the cultural material from Crowder Canyon. This comparative experiment was able to postulate that the feature excavated in Crowder Canyon (see Figure 12), was possibly fired 22 times, if the linear relationship of the data remains consistent through further experimentation. Through my process of approximately one hour of firing and three hours of cooling, I concluded that even firing back to back 22 times would take over 88 hours, which in theory, is not practical to do within one episode of firing. Even if the excavated thermal feature which produced my cultural material was utilized to cook an average of three meals per day this episodic firing would consist of at least a seven-day occupation. If inferring the same theoretical line of thinking for seven firings, back to back firings would span over 28 hours. Considering three meals per day, seven firings suggest at least a two-day occupation. If mass firing was required for a large quantity of food, a large roasting pit would have been utilized for food preparation (McCarthy 2011). Due to the small size of the excavated feature and the fact that yucca stalks were identified as the utilized resource in adjacent features of the same type, we can assume that small-scale firing took place in this feature and that those who occupied the site did so for at least a week or more. While this extrapolation of the data offers sound interpretation, the presented method does not constitute a categorically precise analysis as of yet. However, it does provide a launching pad for further investigation and supports the idea that FAR has analytic utility.

As an archaeologist, I have encountered quite a few cultural thermal features, as well as modern campsites featuring burned rock rings. I have observed through personal observation and recordation in the Transverse Mountain region that modern utilization of burned rock such as modern campsites will be shallow in depth, and include various types of stones placed in a ring formation. Most culturally significant thermal features with a FAR element, however, are predominately the same type of rock, have a depth of 20 cm or more, and have stones that are comparable in size with smoother surfaces that reflect heat more efficiently (Black and Thoms 2014; Crawford 2011). Through my experimental firings, I have been able to provide an additional analytical technique to accompany the identification of cultural thermal features by visual characteristics.

My analytical technique may be important when determining single or multiple uses and can determine firings over time with associated AMS dates of charcoal samples collected *in situ*. This process can be used with multiple forms of archaeological data such as knowledge of available resources, and seasonality of said resources. This process opens the door to comparative analysis with previously studied thermal features in the immediate and adjacent areas and facilitates identification of typological changes between features, providing insight into efficient adaptions over time or within small chronological spans. All of these analyses can be considered within an HBE framework as the basis for resource and settlement patterning decisions. This line of thought would add more contexts to these types of features.

Based on previous research in the Crowder Canyon Archaeological District, we know that the prehistoric inhabitants practiced a logistical settlement pattern with seasonal rounds (Bean and Saudel 1972; Milburn 1998). Excavations such as the one which yielded my cultural material add validity to these previous works. The previous research has uncovered the various resources utilized at these seasonal campsites through microbotanical traces found *in situ*, but my analytical process may answer more in-depth lines of questioning. Can FAR analysis be utilized as a mechanism for determining reuse? The probable answer is yes. While I may not have conclusively determined this as fact, I have shown that through my experimentation there is a practical use for my analysis. I have found that it is possible that the cultural material collected could have been fired at least 22 times, and that extrapolates to at least a week-long stay at that site. If further firings and an upper firing limit were completed on the comparative non-cultural material, it would be possible to determine the exact number of firings. If thermal feature associated charcoal AMS dates ever become available it would be possible to determine the time frame of use or a range of multiple uses. For instance, had more experimental firings taken place including an upper firing limit, and the results from further experimentation resulted in stones that were fired several hundred times on average, we can assume with charcoal AMS date ranges, that it was likely this thermal feature was reused over several seasons within the date range. This theoretical line of thought can answer questions pertaining to seasonal mobility rounds and site reuse. Other thermal features can be analyzed the same way. At that point, we would have a sample of features with analyzed FAR completed. From this information we could extrapolate technological variations that would provide insight into a change in strategies or a change in dietary resources if the stones were fired for shorter periods of time, indicating a shorter processing time.

Future questions that can be investigated through my analysis include: Is it possible to isolate a seasonal round based on the number of firings of a single grill? How many times might the thermal feature have been reused over time? How long was a single habitation episode? My results have shown that FAR analysis does indeed constitute a mechanism for further determination. By investigating the accompanying questions my analysis can better detail and prove patterns of occupation and mobility by the inhabitants of Crowder Canyon and elsewhere.

## Examination into the Utility of Fire-Affected Rock

FAR has been thrown out and considered of limited analytical capacity over the last few decades. A paradigm shift into FAR interest started with Thoms' (2009) replicative work into “hot-rock-cooking facilities” that noted they were utilized throughout western North America and identified archaeological signatures for various types of features. While his research focused on the archaeological signature of these features it provides little more than quasi-typological information of generic features. His work may help archaeologists identify a broad spectrum of thermal features which include FAR, however it does not deal with FAR directly. The feature is taken into consideration more so than its constituents. These stones were still no more than an attribute of a feature's typology. My hope is that this experimental analytical process stands as one of the first steps in a paradigm shift into an archaeological future where FAR is more than a catch-all throw-a-way category of artifact. I have shown that it is possible for FAR to carry diagnostic utility. With further experimentation, it can be considered a diagnostic tool and given more consideration in future analytical studies.

# CHAPTER NINE

# SIGNIFICANCE

## Theoretical Significance

Throughout North American and on every continent thermal features have entered the archaeological record. While they have been given little more than vague typological inferences, I do consider them to be a specialized processing facility. They range in size from small nuclear family utilized grills designed to process small amounts of food resources to very large roasting pits designed to accommodate large communities during harvesting periods. The implications of such obviously significant variation within and between sites and across space and time merit far more scrutiny (Black and Thoms 2014). Very little has been done to associate FAR from thermal features with the archaeological record. Often, these items are excavated from a feature, measured, weighed, and discarded.

This research, however, shows that FAR may have important analytical capabilities that can aid in understanding important cultural components such as mobility, site use, and seasonal patterns. We can also gain insight into episodic site use. We can calculate the number of firings for these stones, and with the use of other analytical means such as AMS dates, we can infer temporal factors to episodic firing.

## Regional Significance

As mentioned previously there are hundreds of recorded sites in this region of southern California that have some sort of FAR element to them. Hundreds of sites could yield thousands of individual features containing FAR. As White (1980) previously argued, the continual disregard of numerous artifacts and cultural material constitutes a cavalier way of documenting the archaeological record. My research offers a new tool for providing context, and temporal significance to the mobility information on the inhabitants of the region, and provides support or infer shifts in behaviors, such as changes in subsistence patterns. There is a variety of questions FAR can answer, even if identified with no associated artifact or material, or if found associated with viable carbon samples, diagnostic artifacts or other associated features. FAR is underappreciated and should be reconsidered as a diagnostic artifact. After all, it is one of the most abundant artifacts present in the Southern California region.

APPENDIX A

SCHIST PERMIT

USDA United States Department of Agriculture | Forest Service | San Bernardino National Forest Front Country Ranger District | 1209 Lytle Creek Road
Lytle Creek, CA 92358
909-382-2600 #3 (Voice)
909-887-8197 (FAX)

**File Code:** 2700
**Date:** March 6, 2017

Shannon Clarendon
c/o Amy E. Gusick
Department of Anthropology
California State University, San Bernardino
5500 University Parkway
San Bernardino, CA 92407-2397

**Crowder Canyon Schist Collection Authorization**

Your request to collect Pelona schist in the Crowder Canyon area to be used in an experimental study is approved. This project has been accepted and approved with modifications to your original proposal. You are authorized to proceed with the activities proposed, subject to the following stipulations.

**The following stipulations apply to this project:**

- Contact Forest Service Archaeologist Jay Marshall (909) 382-2866 to coordinate your activities prior to the start of collection.
- The collection will occur within the Crowder Canyon Prehistoric Area in a section which has no heritage resource sites and is not on private land, as delineated in the attached map, shaded in blue.
- The work will be completed before February 7, 2018.

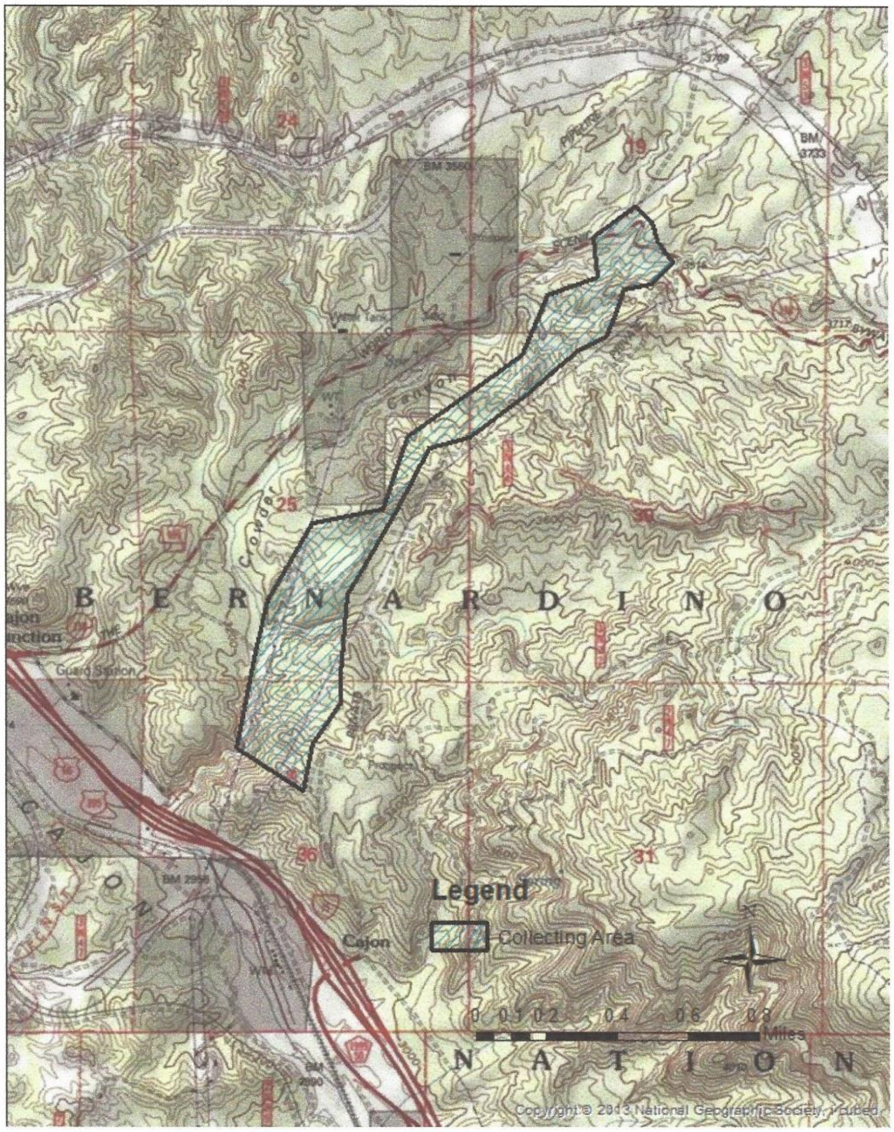
If you have any questions, please contact Jon Rishi, Lands and Recreation Officer, either by email: jrishi@fs.fed.us or phone at 909-382-2940.

Sincerely,

CHRISTINE A. HILL
District Ranger

Enclosure (1)

Enclosure 1. Collection area for 1997051200016 Shannon Clarendon rock collection in blue.



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