

THE UTILITARIAN AND RITUAL APPLICATIONS
OF VOLCANIC ASH IN ANCIENT
ECUADOR

by

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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS.....	iv
LIST OF FIGURES	viii
ABSTRACT.....	xi
CHAPTER	
I. INTRODUCTION.....	1
II. METHODOLOGY.....	7
Previous Excavations and Archaeological Literature.....	9
First-Hand Observations.....	10
Survey and Excavation	11
III. THEORETICAL BACKGROUND.....	13
IV. ECUADORIAN PREHISTORY	21
The Paleoindian/Preceramic Period (ca. 12,000 BP-3500 BC).....	24
The Formative Period (ca 3500-300 BC).....	25
The Regional Development Period (ca 300 BC-800 AD).....	29
The Integration Period (ca 800-1532 AD).....	31
V. MYTHS, VOLCANISM, AND VOLCANIC STUDIES	37
Volcanos in Ecuador.....	37
Mythology of Volcanos in Ecuador.....	41
Evidence of Climate.....	45
Glaciation.....	46
The Sucus Bog Core	47
The Huarmicocha Lake Core.....	49
Volcanism and Volcanic Studies	50
Tephrochronology.....	52
Abandonment and Migration	53

Obsidian Sources	54
Eruptions as Drivers of Change and Chronostratigraphic Markers	55
Pululahua Volcano	55
Quilotoa Volcano	56
Cotopaxi Volcano	60
Discussion	61
 VI. CERAMICS	 63
Clays and Clay Formation	63
Volcanic Ash as Ceramic Temper	65
The Western Montaña	66
Chaupicruz Phase Ceramics from Malchinguí	66
A Comparative Example in the Maya Lowlands	67
The Guangala Culture of Ecuador	70
Highland Formative Period Ceramic Firing Pits	76
Results and Discussion	79
 VII. RITUAL AND BURIAL PRACTICES	 81
Volcanic Ash and the Shaft Tomb Traditions	85
Volcanic Ash and Hemispherical Burial Mounds	87
Volcanic Ash and Pyramid Burials	92
An Anomalous Instance of Volcanic Ash Incorporated in a Burial	94
Results and Discussion	97
 VIII. CONSTRUCTION	 100
The Cangahua Formation: A Pleistocene-age Indurated Volcanic Ash ..	100
Inka Construction Practices from San Agustín de Callo	109
Inka Foundations at Hacienda Guachalá	116
Earthen Pyramid Construction at Cochasquí	129
Recent Excavations at Cochasquí	135
A Comparative Case in the Southeastern U.S.A.	146
The Volcanic Ash Canal of Rumipamba	149
Results and Discussion	150
 IX. CONCLUSIONS	 153
REFERENCES CITED	160

LIST OF FIGURES

Figure	Page
1. Prehistoric Periods of Ecuador by Region.....	23
2. Volcanos of the Interandean Valley.....	38
3. The 1280 AD Quilotoa ashfall extent compared to other ashfall extents.....	58
4. The Lowland Maya Region and Volcanically Active Highlands.....	68
5. The south coast of Ecuador with the Santa Elena Peninsula.....	71
6. Guangala fine-paste, white on red, and coarse-paste ceramics.....	73
7. Guangala fine-paste polychrome.....	74
8. Class 1 pumice inclusion.....	74
9. Plan map of open-air firing pit lined with Cuicocha ash.....	78
10. The extent of highland Ecuadorian and Colombian shaft tomb traditions.....	82
11. Various highland Ecuadorian and Colombian shaft tombs.....	84
12. Profile drawing of Mound a showing intentional layering of tomb sediments and the discard of the original sediments.....	90
13. Layered sediments from the tomb shaft within Mound a.....	92
14. An apparent shaft tomb (marked with red) within the pyramid at San Rafael.....	94
15. Burial recovered from the slopes above Huaracuí.....	96
16. Distribution of the Cangahua Formation within the Interandean Valley.....	102
17. Rough-cut <i>cangahu</i> blocks from a pyramid at San Rafael, Ibarra Province.....	106
18. Pillowed <i>cangahua</i> blocks forming the lower tiers of Pyramid G at Cochasquí.....	108

19. Coursed masonry-style <i>cangahua</i> wall from Pyramid G at Cochasquí.....	109
20. Inka Construction at San Agustín de Callo.....	110
21. Quilotoa ash washed off of Inka wall foundation.....	112
22. Sediments abutting the Inka wall foundation.....	113
23. Foundations beneath the chapel at San Agustín de Callo.....	114
24. Hacienda Guachalá 2011 Trench 1 location.....	118
25. Trench 1 chapel foundations.....	119
26. Exterior wall foundations near the former corner.....	121
27. Unit and trench locations within the Hacienda Guachalá Chapel.....	122
28. 3D photo model of Hacienda Guachalá.....	124
29. Chapel foundations within Unit 5 showing intentional layering of sediments.....	127
30. Aerial view of Pyramid G.....	131
31. The central corridor of Pyramid G.....	131
32. Earthen floors exposed within the western cut profile indicated by red arrows.....	137
33. Carved <i>cangahua</i> block from atop the lower earthen floor.....	137
34. Pumice and <i>cangahua</i> chunk dense layer.....	142
35. Alternating dark and light sediments exposed within the western cut profile of Pyramid G.....	143
36. A portion of the Pyramid L profile documented by grupo del trabajo Ecuador.....	143
37. Alternating dark and light layers from Monk’s Mound, Cahokia, U.S.A.	148
38. Canal-like volcanic ash feature at Rumipamba.....	150

LIST OF ABBREVIATIONS

Abbreviation	Description
AD	Anno Domini
BC	Before Christ
BP	Before Present
ca	circa
uncal	uncalibrated
VEI	Volcanic Explosivity Index

ABSTRACT

While the majority of studies on volcanic ash in Ecuadorian archaeology are focused on tephrochronology or regional abandonment, there has yet to be a study conducted on the different technical and ritual applications of volcanic ash. Volcanic ash has a great deal of unique chemical and physical properties that make it ideal for a wide variety of technical uses. These same properties make volcanic ash useful for a number of analyses that can yield clues to ancient technical knowledge, areas of influence, and systems of exchange. As a distinctive byproduct closely associated with devastating volcanic eruptions, volcanic ash held great symbolic significance and was used for many ritual applications as well. The ways in which ash was used in these ritual settings can yield clues to ancient conceptions of volcanos and the intricacies of human-volcano relationships. Because volcanic ash was used by various cultures for different purposes, archaeological remains of these uses can serve as culturally and temporally diagnostic markers in the archaeological record. This thesis seeks to catalog these different uses so that they might serve as a reference for other researchers examining volcanic ash features and to discuss them in such a way that it might better our understanding of the complicated relationship ancient people had with these most imposing features of the landscape.

I. INTRODUCTION

In many ways, volcanic eruptions define the pre-Columbian history of Ecuador. Through millennia, the imposing presence of the volcanos on the northern Ecuadorian landscape inspired fear and veneration, with the ever-present threat of disaster the price of life-giving sources of water. Ecuador is one of the most volcanically active countries on earth, and it's impossible to examine the archaeology of the country without considering both the direct and indirect impacts of volcanic eruptions. While the cultural traditions of Peru and the Andes to the south have been extensively studied over the last two centuries, the groups that prehistorically occupied the northern portion of the Andes remain relatively enigmatic. Located at the boundary between Andean cultural groups to the south and the Caribbean cultural groups of the so-called Intermediate Area of Colombia, Venezuela, and Panama to the north, the cultures of Ecuador unsurprisingly demonstrate aspects of both regions. Because of their placement along a transition zone between recognized regions, researchers have struggled to categorize these people, often wavering between comparisons to groups found in the Peruvian Andes and groups from Colombia to the north. Unlike their neighbors to the south, many of the Ecuadorian groups largely forwent construction made of stone in favor of construction produced using more malleable and readily available earthen materials. The extreme volcanic environment of the northern Andes and the unique Equatorial setting provides the people there with a variety of volcanically produced materials, some of which can be found in no other part of the world. Though the importance of these materials has long been recognized, little attention has been given to how access to these materials and the environmental processes associated with them has shaped the development and identity

of the local people. This work seeks to expand our understanding of Ecuadorian groups through an examination of their relationship to their environment via the applications of these unique local materials.

Explosive volcanic eruptions produce pyroclastic flows and lahars which bury archaeological sites, inundate natural resources such as ceramic clay sources, and significantly alter the landscape. These eruptions also produce tephra, often loosely referred to as volcanic ash, which can have various effects on soil acidity as well as plant and animal life resulting in impacts on the natural environment, agriculture, and human health. Much of the archaeological research related to volcanic eruptions in Ecuador has used volcanic ash to focus on eruption impacts in the form of ashfall extent and distributions, tephrochronology, effects on local communities, and understanding regional abandonment and forced migrations (Athens 1998; Hall and Mothes 1998; Lippi 2003; Mothes and Hall 1998). Yet, despite its chaotic and destructive associations, volcanic ash has unique chemical and physical properties that can make it ideal for an array of different uses. Numerous pieces of archaeological evidence indicate that volcanic ash was used by a variety of cultures for an array of purposes, both utilitarian and nonutilitarian, throughout the prehistory of Ecuador. As such, these different uses have the potential to be both culturally and temporally diagnostic markers in the archaeological record, not only by attributing sites or components of sites to a particular group, but also by tracing various phases of construction within individual architectural features to a specific group during a specific time period. These uses also represent a concerted effort to gather constitutively appropriate materials for specific utilitarian or nonutilitarian

functions and are not simply the product of least-cost procurement. As such, they have the potential to inform on patterns of exchange and areas of cultural influence.

To date, no comprehensive study on the variety of uses of volcanic ash in ancient Ecuador has been conducted. In this thesis, I have composed an in-depth study of existing archaeological and historical literature supplemented by limited archaeological fieldwork to construct a catalog of known uses of volcanic ash, potential uses that may have been overlooked, and previously undocumented uses in order to provide information on technological understanding, areas of cultural influence and exchange, and ideological as well as ritual practices. While this study is primarily focused on the prehistoric uses of volcanic ash, where applicable and where evidence of continuity might be demonstrated, I discuss how these prehistoric practices have influenced historic and contemporary practices.

The primary goals of this study are three-fold:

1. To create a catalog of the uses of volcanic ash that can serve as culturally and temporally diagnostic markers, not only to identify individual sites, but also to identify specific architectural components of a site and relate them to particular cultural groups or cultural practices.
2. To document uses that are the result of ancient technical knowledge and long held traditions which, in many cases, have continued unrecognized from prehistoric times into the modern era. Thus, the different uses may offer insight into the development of architectural and ceramic practices through the prehistoric period, into the historic, and even into contemporary times while also providing inspiration for new and innovative contemporary uses.

3. To understand that volcanic ash, as the byproduct most closely associated with volcanic eruptions, has the potential to inform about the ideological role of volcanoes in the region. Ecuador, like much of the Andes, is rife with mythological accounts of the role of volcanos but oddly devoid of explicit iconographic representations. Understanding the relationship local groups had with volcanic ash based on its symbolic uses could serve as the keystone in understanding ideology, cosmology, and mythology.

Due to the concentration of active volcanos in the northern Ecuadorian highlands and the resultant tephra deposits found there, most but not all of the examples mentioned in this thesis are drawn from that portion of the country. As much of my previous experience and research has been concentrated in the northern highlands among the Barbacoan speaking groups who appear to have had an intimate relationship with the volcanos in the region, many of the examples mentioned come from this area. When appropriate, examples are taken from the southern highlands where ancient ash deposits are present and from coastal regions where volcanic ash from highland eruptions was naturally deposited or artificially imported.

Much of the theoretical approach applied to this work is drawn from landscape theory and the isochrestic perspective. Landscape theory seeks to find a balance between environmental determinism and the aspects of cultural agency that influence peoples' conception of their landscape. Landscape theory views conceptions of landscape as the application of culturally relevant meaning to inherently meaningless aspects of the environment. The isochrestic perspective is a functionalist perspective that views items in a culture as serving both utilitarian and nonutilitarian functions. Utilitarian functions are

those with a specific material purpose such as tools, weapons, or construction materials. Nonutilitarian functions are those more closely related to beliefs or ideology such as religious symbols or status symbols. In either case, every item serves both utilitarian or nonutilitarian functions to a greater or lesser degree, but one of these functions is the primary while the other is the secondary.

Landscape theory is applied with the idea that the development of local groups was influenced by their conceptions of the volcanic environment. The isochrestic perspective suggests that particular types of volcanic ash were chosen for specific purposes based on their availability as well as their constituent chemical and physical properties or for their symbolic or ideational value. The utilitarian aspect of volcanic ash is especially relevant when analyzing construction and ceramic production. However, when analyzing some of the more nuanced aspects of mound construction and burial practices, it is useful to consider the broader systems of belief that may have influenced the conscious and unconscious choices of the people that conducted these practices. Why were certain sediments and ash types chosen over others and what do these choices tell us about the symbolic meaning engrained in these actions and in their final product? Where little information is available on the ideology of the local groups due to a lack of iconography and ethnographic texts, as is the case in much of highland Ecuador, it is helpful to draw on broad historical and contemporary accounts of mythology as well as expand our purview to make cross cultural comparisons.

Chapter II of this thesis lays out the methodology applied in the collection and analysis of archaeological literature as well as in the limited fieldwork conducted for this thesis. In Chapter III, the theoretical framework of this thesis is outlined in more detail.

Chapter IV discusses the cultural and historical background of prehistoric Ecuador and the different groups mentioned in this work. Chapter V seeks to contextualize human-volcano interactions through the mythology of the region, the history of some of the more notable volcanic eruptions, and the impacts of eruptions on cultural developments. In Chapter VI, the use of volcanic ash in different aspects of ceramic production based on existing archaeological literature is outlined. Chapter VII provides an overview of burial practices in which volcanic ash was intentionally incorporated in either a significant cultural tradition or in isolated cases documented at different archaeological sites. Chapter VIII describes the variety of uses of volcanic ash, pumice, and other forms of tephra documented throughout Ecuadorian prehistory the use of which, in some cases, continues into the historic and contemporary times. The final chapter of this thesis, Chapter IX, summarizes some of the broad conclusions that can be reached based on the variety of cases presented in this thesis.

II. METHODOLOGY

Because setting out to find instances of volcanic ash uses archaeologically through new field work was a far too time consuming and costly effort for the purpose of this work, most of the data collected and presented here has come from the examination of existing archaeological literature. Volcanic ash in varying forms is so ubiquitous throughout Ecuador that few research papers are ever produced without mentioning it in some way, though there has yet to be a study that compiles this data and examines it systematically. I searched for known uses of volcanic ash, identified volcanic ash features, and attempted to identify instances where volcanic ash uses have been overlooked, misidentified, or had not been discussed in significant detail. I have documented these instances here, described them to the best of my ability based on the available materials, drawn comparisons to other documented instances of ash use in Ecuador and other regions of the Americas, and attempted to provide some basis for their use. In many cases, it can be difficult to determine if volcanic ash encountered during excavations was included intentionally or was the result of a chance encounter with a natural deposit. This is especially true when examining mound and pyramid construction or burial practices. Whenever reasonable, I include instances which may be, but are not certainly, intentional inclusions of volcanic ash and potential explanations for their inclusion.

Where relevant, I have drawn from my own nine years of experience researching, surveying, and excavating in Ecuador. Much of my previous research has been focused in the northern Ecuadorian highlands which is the most volcanically dense region of the country and, as such, the region of the country with the most volcanic ash deposits. Thus,

many of the examples presented here are drawn from this region, with special attention placed on the site of Cochasquí where I have conducted research over the last four years. I also conducted limited archaeological fieldwork for this study between June and July of 2018 in the form of both targeted survey and excavation to collect photos, notes, and samples of yet undocumented or poorly documented ash uses. In some cases, I searched for undocumented uses of volcanic ash that may have been found but initially overlooked through discussions with locals and other archaeologists.

As examples of volcanic ash uses were collected, I identified three major areas where volcanic ash use was most prominent: ceramic production, ritual and burial practices, and construction. These groupings were further divided based on the particular practice within in each category which was frequently related to grain size (e.g. foundation, mortar, or insulation). Whenever possible, ash was traced back to its parent volcano and source eruption either through extant literature or through samples taken and identified in the field. The date of the source eruption was estimated using the information provided by existing volcanological and archaeological literature or the Smithsonian Volcanism Project's online Volcanos of the World database. The date of the eruption provides a *terminus post quem* or "no-earlier-than" date for the resultant use or archaeological feature. Additionally, site location was assessed in relation to the known extent of ashfalls and, wherever the information existed, the general quarry location from which the ash was collected was identified. Thus, the method of use or resultant feature could be contextualized in instances in which the constituent ash required long-distance travel or exchange to procure.

Previous Excavations and Archaeological Literature

The study of volcanic ash has proven to be especially useful in dating archaeological contexts as well as understanding regional abandonment and migration patterns (Athens 1998; Hall and Mothes 1998; Isaacson 1987; Mothes and Hall 1998). Volcanic eruptions produce ash with unique chemical and physical compositions allowing newly located ash layers to be attributed to a specific volcanic eruption at a specific time. Because volcanic eruptions naturally lay ash down in horizontal layers, ashfall deposits dated either through relative dating, historic observations, or radiocarbon samples can be used as reference markers in the archaeological record, a process known as tephrochronology. Consequently, the chemical and physical properties that make the ash recognizable as well as the distribution of volcanic ashfall from major eruptions are fairly well studied and widely used in archaeology (Mothes and Hall 1998). As such, the presence of volcanic ash is typically documented whenever it is encountered in the archaeological record along with descriptions of texture and inclusions as well as potential source eruptions making descriptions of volcanic ash often more well represented in the literature than other types of strata. Because of this, I was able to comb through existing archaeological reports and publications in search of any mention of volcanic ash, assess whether the ash represented an intentional archaeological feature or a natural deposit, and determine potential reasons why the inclusion of ash would have been intentional for either utilitarian or ritual functions.

Though numerous examples of volcanic ash features and uses have been documented in Ecuador, they have not yet been compiled into a single work and their potential utilitarian and ritual functions are often overlooked or poorly posited. I sought

to remediate this situation by compiling similar instances of volcanic ash uses, organizing them based on their similarities for the sake of comparison, and attempting to map their locations in order to understand their geographic extent. In many instances while presenting at conferences or speaking to other archaeologists working in Ecuador, I found that others had encountered volcanic ash in different contexts but had not considered the possibility that it had been intentionally placed and, as such, had not properly recorded the find. Where this was the case, I learned what I could about the site and context of the ash and attempted to provide a description based on the information provided.

First-Hand Observations

During my time working in Ecuador, I have personally encountered and documented several instances of volcanic ash used intentionally in construction. Though my techniques over the years have varied, wherever possible the physically tangible properties of the ash such as texture, grain size, whether they have been sieved, levigated, floated, naturally combined, or artificially mixed with another material was described and a potential date and source eruption suggested. Though an in-depth chemical analysis of volcanic ash composition would have undoubtedly be useful, chemical testing of ash samples is largely beyond the scope of my previous research or this study. Because volcanic ash is naturally sorted by the wind before it is deposited, with large pumice falling close to the source and fine powdery ash being carried great distances, the grain size of ash gathered for some use can indicate a collection location relative to the source volcano. Thus, grainsize in conjunction with knowledge of localized ash layers was used to suggest if ash from archaeological features was gathered from the surrounding area or imported some distance from the original find location.

Survey and Excavations

In June of 2018, I returned to the archaeological park of Cochasquí as part of the ongoing Proyecto Arqueológico Cochasquí-Mojanda to conduct limited fieldwork for this thesis. I spent approximately two weeks in Cochasquí profiling exposed cuts, previously exposed excavations, and open looters' trenches. Most of the early archaeological work at Cochasquí was conducted by Udo Oberem and his crew from Germany in the 1960s who spent a year bisecting and trenching mounds and pyramids at the site (Oberem and Hartman 1981). The Germans did not backfill after their excavations at the request of the landowner and left all of their cuts exposed, although some excavations have since been filled by the park in an effort to preserve the site. Because Oberem and his crew were more concerned with macrostratigraphic units as they relate to phases of construction, they did not provide much detail on soil descriptions or microstrata that might represent carefully selected individual basket loads. As such, there is a great opportunity at Cochasquí to profile existing exposures in numerous mounds and pyramids without the need for intensive excavations. Most of my time at the site was spent working on Pyramid G, the largest pyramid on site which was significantly altered by the landowners who excavated two trenches through the pyramid in the early 1900s when the site was still part of a hacienda. Pyramid G is the only large pyramid on site with sufficient open exposures to warrant significant investigation. Additionally, I spent some time examining the previously produced profiles and exposed excavations of Mound x, called *Uspha Tola* or "Ash Mound" by the locals, a possible habitation mound which had been bisected by the adjacent roadway. I also examined some of the smaller burial mounds which had been excavated and left exposed for evidence of ash features included in their construction.

In addition to profiling at Cochasquí, I spent approximately two weeks travelling to different sites around northern Ecuador conducting a targeted survey collecting photos, drawings, and notes on pre-exposed excavations as well as following up on different rumors I had heard of ash uses and features. I also visited exposed excavations with potential ash features at the sites of Rumipamba and La Florida in Quito (which are now archaeological parks) as well as a bisected pyramid at the site of San Rafael near the town of Otavalo. Evidence of intentional ash features was found at all three sites and was documented appropriately to the best of my ability given the respective level of available access at each site. As with my previous research, the physical properties of the ash were documented and, whenever possible, a potential date and source eruption was suggested.

III. THEORETICAL BACKGROUND

Two primary theoretical perspectives were largely implemented for the purposes of this study. The first and most obvious perspective when examining ancient uses of volcanic ash is a functionalist approach. The functionalist perspective views particular cultural practices as serving a broader function within the cultural system in which they operate. The aspects of the functionalist perspective drawn on for this thesis are based largely on the isochrestic approach originally outlined by Sackett (1981). Sackett sought to augment Binford's (1962) concepts of technomic, socio-technic, and ideotechnic items in a way that was more in line with Middle Range Theory. Though Sackett and Binford were writing specifically in reference to Mousterian lithic technology, the concepts outlined by them were framed within broader applications to archaeology in general and have since been used to analyze cultural phenomenon amongst other groups from numerous time periods.

In the isochrestic perspective, function, when viewed within its original cultural context, includes material concepts such as technology and economics, societal concepts such as social organization and behavior, and ideational concepts such as ideas, beliefs, and values. Function can be divided into two primary domains. The first of these is the utilitarian domain, which in Sackett's original discussion includes things such as technology, weapons, and material byproducts. The second is the nonutilitarian domain which serves as the primary vehicle for expressing social relations and ideas. In every case, whether the nonutilitarian or utilitarian domain is most appropriate as the primary grouping, it is crosscut by an "adjunct" secondary domain which exhibits the attributes of

the other. Thus, every item exhibits utilitarian and nonutilitarian aspects to greater or lesser varying degrees.

I utilize this approach to suggest that utilitarian concerns are often the primary reasons for the inclusion of volcanic ash for many of the cultural practices outlined in this thesis and that particular types of volcanic ash were chosen for specific purposes based on their wide availability as well as their constituent chemical and physical properties. This is especially true when analyzing construction and ceramic production. Yet these uses always have, to greater or lesser extents, nonutilitarian aspects indicative of social and ideational practices. The isochrestic approach forces us to recognize the importance of the interplay between the utilitarian and nonutilitarian aspects in forming recognizable variants or styles. As such, even though I might limit a discussion to a single aspect, utilitarian or nonutilitarian, where one is more predominantly recognizable, it should not be taken as a refutation of the considerations of the other aspect, but rather an acknowledgement that evidence of this aspect may not be readily available.

When analyzing some of the more nuanced aspects of mound construction and burial practices, the nonutilitarian aspects may be the primary domain and it may be useful to adopt a theoretical perspective more focused on social or ideational function to consider the conscious and unconscious choices of the people that conducted these practices. Why were certain sediments and ash types chosen over others and what do these choices tell us about the meaning engrained in these actions and in their final product? These choices were limited by the social constraints and traditions in which they were made and, as such, represent symbolic subconscious reflections of their original cultural context (Sackett 1989). In this sense, these choices operate as a sort of habitus

that, though often unrecognized by the individual, represent the trace material remains of the sociocultural framework in which they were created. Habitus represents the often unconscious behaviors and choices that are made within the context of culturally dictated social frameworks (Bourdieu 1989). Choices are considered to be acceptable or unacceptable based on the structure of this framework, though the acknowledgement of these limitations frequently goes unrecognized by the group and its members. Although an infinite variety of choices could be made for the form of a pot or the shape of a projectile point, often only those choices deemed to be “acceptable” by the culture within which the artisan is operating are considered.

The other major theoretical approach applied to this work is drawn from the concept of landscape theory. In anthropology and sociology, landscapes are social and cultural constructs created by a group’s symbolic interpretations of their environment (Anschuetz et al. 2001; Greider and Garkovitch 1994; Knapp and Ashmore 1999). They are ways in which groups assess inherently meaningless natural environmental phenomena and apply culturally specific meanings to them in a manner that allows groups to reconcile culture with nature through habitus. As such, landscapes do not represent the natural environment, but rather the culturally relevant conception of that environment and a reflection of the social structure in which it was developed. It is through the conception of landscapes that places may become recognized by a group as sacred, fertile, barren, civilized, or uncivilized. These meanings are ever changing, both between and within cultures, through time and thus come to represent a broad cultural history (Anschuetz et al. 2001). Understandings of landscape are so deeply engrained in cultural narratives that they become synonymous with individual and group identity,

often holding constant even if the landscape changes (Greider and Garkovitch 1994). A notable example of this in the Andes might be seen in the Inka tendency to rename natural features on the landscape around cities such as Tomebamba and Quito to conform with locations around the capital of Cuzco (Salomon 1986).

Just as the isochrestic perspective seeks to find a balance between functionally specific determinations on aspects of culture with social and ideological considerations, so too does landscape theory seek to find a balance between the environmentally deterministic aspects of peoples' relationship with their landscape and the culturally engrained symbols and meanings that are applied (Greider and Garkovitch 1994). Landscape theory also emphasizes not just the symbolic aspects of the natural environment, but their relationship to the creation of complex cultural landscapes. The landscape theory approach places more emphasis on first understanding the cultural symbols that represent aspects of the landscape before attempting to understand how these cultural symbols are applied (Greider and Garkovitch 1994). It is in this effort that the practice of archaeology may be a bit at odds, as we often believe we can more readily understand the relationship with the environment and the relevant cultural symbols must then be inferred. Understanding this symbolism then might require supposition and upstreaming on the part of the archaeologist. However, as many of these symbolic understandings represent doxa and thus go unrecognized by their practitioners, they are more readily observable from the etic perspective that archaeology lends.

Though originally developed by geographer Carl Sauer (1925), the concept of landscape theory was incorporated into the discipline of archaeology and became widespread during the 1990s (Knapp and Ashmore 1999). Literature on landscape theory

in archaeology general focuses on three major aspects: settlement ecology, ritual landscapes, and ethnic landscapes (Anschuetz et al. 2001). This thesis seeks to employ landscape theory in a way that incorporates all three of these aspects to varying degrees. The settlement ecology aspect of landscape theory centers on the relationship between conceptions of the landscape as they relate to social structure, organization, and change (Anschuetz et al. 2001). It recognizes that small scale social or organizational change might represent minute changes in interactions with the environment while large scale changes may be necessitated by rapid and dramatic changes to environmental relationships such as those that might take place after a volcanic eruption. In this sense, changes in conceptions of landscapes are more representative of internal cultural changes than external environmental changes (Greider and Garkovitch 1994). Thus, this aspect of landscape theory recognizes the internal cultural processes that the environment influences. The environmental changes may influence the cultural changes which dictate conceptions of landscape, but they do not outright influence the conceptions of landscape. Variations in the archaeological record are therefore representative of social changes indicative of these evolving perceptions of landscape.

Ritual landscapes represent the relationship between the environment and a group's conception of their cultural narrative in the form of history, mythology, power, and cosmology (Anschuetz et al. 2001). Researchers seek to understand the relationship between the natural environment and the distribution of sacred structures, features, and places on the landscape in contrast to habitation and activity areas. The location and orientation of ritual structures is the result of doxic reflections of the conceptions of the landscape and the notion that they represent the ideal arrangement for the way things

should be. Frequently, the interpretation of ritual landscapes is dependent on contemporary ethnographic and ethnohistorical comparisons. Where little information is available on the ideology of the local groups due to a lack of iconography and ethnographic texts, as is the case in much of Ecuador, it is helpful to draw on broader historical and contemporary accounts of mythology as well as expand our purview to make cross cultural comparisons with more well studied regions of the world.

The focus on ethnic landscapes seeks to define ethnicity through shared material culture and symbols that might represent shared conceptions of landscape (Anschuetz at al. 2001). The concept is based on the premise that conceptions of landscape become culturally relevant reflections of the groups that created them. Ethnic landscapes in archaeology are broadly demonstrated in the concept of “culture areas” in which regions are defined by the shared lifeways of the people that inhabit them (Anschuetz at al. 2001). Some of the strongest evidence for the connection between group identity and conceptions of landscape can be seen in the tendency to link ethnic and political divisions to the most prominent volcanic peaks. Many groups view the most prominent volcanic peaks in their region as the progenitors of their ethnic group (Caillavet 2000; Paz Maldonado 1897 [1582]) and many provinces and *cantóns* (an administrative subdivision similar to a district) in Ecuador today still take their names from these peaks. Perhaps more than any other single feature of the landscape, volcanos are linked to group identities, underscoring the importance that volcanos play in the cultural narratives. As always, the identification of ethnicity in archaeology is tenuous at best and it’s unclear if archaeologically defined ethnicities based on conceptions of landscape translate into real self-maintained conceptions of identity.

A new dimension is added to landscape theory when we consider the possibility that features of the landscape have autonomy and represent symbolic actors in the broader cultural landscape. In this way, local groups lend agency to natural features of the landscape allowing them to play active roles in cultural narratives. This is certainly relevant when considering the role that volcanos play in the broader interactions with ancient groups and their landscape. Perhaps more than any other natural feature, volcanos are capable of almost immediately changing the natural environment and landscape. Thus, natural phenomena such as volcanic eruptions and the subsequent morphological and environmental changes are interpreted in culturally relevant ways reflective of the relationship between local groups and these locations on the landscape.

The landscape theory approach applied in this work is based on the idea that the development of local groups was influenced by their relationship to their volcanic environment and the conceptions of that environment were influenced by their own conceptions of their culture. This is certainly a useful perspective when examining the use of earthen materials. There is a reciprocal relationship between the utility that people receive from earthen materials and their conceptions of the locations from which those materials are received. Volcanic ash, as one of the primary byproducts of volcanic eruptions, perhaps more than any other material represents these events. Once removed from its original context, volcanic ash becomes an artifact in the archaeological record and the procurement, processing, and transportation of the material can be studied just as any other archaeological material. The choices behind which types of ash to use and the way in which ancient people chose to use the materials in both utilitarian and nonutilitarian ways is representative of their relationship with the volcanos and these

events. The final products of this use thus may serve as the material symbols of this relationship. The examination of earthen construction of mounds and pyramids especially, as it represents the creation of both a cultural landscape in the form of sacred structures and a physical landscape which may mirror conceptions of the natural landscape, can inform on this relationship. This thesis seeks to illuminate the variety of volcanic ash uses in order to better understand the reasoning behind these choices, the broader sociocultural framework in which they were made, and the symbolic relationship between the ancient people of Ecuador and their dynamic landscape.

IV. ECUADORIAN PREHISTORY

Archaeology of Ecuador is frequently discussed in terms of three major geographic regions: the Coast, the Highlands, and the Amazon. The varying geography and ecology of these regions results in different subsistence patterns and lifeways, which make the division appropriate in most instances. The Amazonian lowlands and much of the Pacific coast of Ecuador are characterized by dense tropical vegetation reliant on heavy seasonal rainfall fed by moisture from the Pacific Ocean and the Amazon basin, which dissipates as it rises along the eastern and western slopes of the Andes. This moisture in the form of clouds provides a near constant water source for the eastern and western montaña (cloud forest). Along the southern coast of Ecuador, the region is dominated by a drier desert-like environment fed by intermittent and ephemeral streams, which appear during bouts of heavy rainfall. In the northern highlands, tall mountain peaks are interspersed with volcanos many of which are covered year-round by montane glaciers that serve as the primary water source for the streams and rivers in the valleys below (Espinosa et al. 2018). From prehistoric times until around the 18th and 19th century, these montane glaciers extended across many of the prominent mountain peaks (Heine 2011). High elevation grasslands spread across much of the mount ranges between the forested river valleys and the highest mountain peaks. In the southern highlands adjacent to the Gulf of Guayas near the Cuenca basin, the Andes mountain range dips providing much less drastic differences in relief and easier flow of movement for plants, animals, and humans (Guffroy 2008).

Ecuadorian prehistory is generally divided in to four periods based on different levels of cultural interaction and technological development (**Figure 1**). The dates of

these different periods vary by author, region of the country, and the date at which they were produced. The dates provided here are based on the work of various authors working in various regions (Lippi 2003; Porras 2008; Valdez 2008; Zeidler 2008) and, as such, are somewhat generalized. The earliest of these four periods is the Paleoindian Period (sometimes referred to as the Preceramic) which dates from the time of the first evidence of humans in Ecuador as late as 12,000 BP or perhaps as early as 15,000 BP until approximately 3,500 BC. Though recently there has been a push for the designation of an Archaic Period between 10,000 BP and 3,500 BC, this period is still poorly defined and not widely recognized. The following period is known as the Formative Period, which is dated between 3,500 and 300 BC. The subsequent period after the Formative Period is known as the Regional Development Period which dates between 300 BC and 800 AD. The final recognized period in Ecuadorian prehistory is the Integration Period from 800 AD until the Spanish contact around 1532 AD. While innumerable cultures occupied the different regions of Ecuador during these different periods, an in-depth discussion of all of these respective cultures is beyond the scope of this study. The following description is instead focused mostly on the archaeologically recognized cultures mentioned in this thesis and their respective periods with particular attention paid to the aspects of these groups that are relevant to the volcanic ash studies presented here.

PERIOD	COASTAL LOWLANDS			HIGHLANDS (SIERRA)			EASTERN LOWLANDS (ORIENTE)			DATES		
	NORTH	CENTER	SOUTH	NORTH	CENTER	SOUTH	NORTH	CENTER	SOUTH			
SPANISH CONTACT										1532		
INTEGRATION	Atacames II Balao Atacames I Tumbavido	Manteño	Inca		Negativo Carchi Capuli / Tuza (Piartal Cuasmal) Cochasqui Chaupicruz	Inca		Napo	Pastaza D	Bracamoro	1480	
	Las Cruces Cantarana Herradura	Jama Coaque II	Huancavilca	Milagro Quevedo		Catacocha Cariamanga	Caranqui Panzaleo/Cosanga Puruha Tunahuan Cañari (Cashaloma) (Tacalshapa)	Cosanga Pillaro III-IV			Upano III	700-800
			Jambeli					Cosanga Pillaro I- II				
REGIONAL DEVELOPMENT	Guadual Tiaone Tolita Tardío Selva Alegre La Tolita	Bahía II Guangala Jama Coaque I Bahía I	Tejar	Daule	La Florida	Cerro Narrio II	Yasuni	Pastaza C	Upano II	0 300		
			Engoroy					Tihuacuno				
LATE FORMATIVE	Mafa Tolita Temprano Tachina	Tabuchilla	Guayaquil	Chorrera	La Chimba	Cerro Narrio I Chaulabamba	Catamayo D	Cotundo	Tacana	1000		
							Catamayo C	Upano I				
MIDDLE EARLY	Machalilla				Cotacollao	Alausi	Catamayo B	Pastaza B	Los Tayos Mayo Chinchi	1500 2500		
	Valdivia						Catamayo A	Pastaza A PreUpano		3000/5500		
Archaic	Las Vegas									6000/9000		
Paleoindian					El Inga	Chobshi	Cubilan	Jondachi		10 000 -/ 15 000		

Figure 1: Prehistoric Periods of Ecuador by Region (from Valdez 2008).

The Paleoindian/Preceramic Period (ca. 12,000 BP-3500 BC)

Two of the earliest Paleoindian/Preceramic cultures in Ecuador are the El Inga culture, first recognized in the Quito basin, and the Las Vegas culture of the Santa Elena peninsula. The earliest evidence of humans in Ecuador comes from the site of El Inga in the Quito basin near Ilaló. The surface collections and excavation at the site in the 1960s yielded an impressive assemblage of lithic artifacts including several distinct point types that have come to define the El Inga Complex, also known as the Ilaló Complex. Many of the different point types exhibit evidence of fluting. El Inga Broad Stem points have been identified as far north as northern Colombia and Panama (Mayer-Oakes 1963; Pearson 2017). These points appear to be part of a larger northern-South America tradition in which innovation and experimentation are visible in fluted projectile point assemblages. Unfortunately, no reliable radiocarbon samples could be found to date the occupation at El Inga, but obsidian hydration and similarities with Clovis technology have led to the suggestion that El Inga dates to around 12,000 BP (Mayer-Oakes 1986; Gnecco 1994).

The Las Vegas culture is possibly one of the earliest sedentary or semi-sedentary cultures of Ecuador and was located on the Santa Elena Peninsula, north of the Gulf of Guayaquil. Stothert (1988) identified Las Vegas as being unique in that it is a preceramic coastal tradition, the only known preceramic coastal tradition in Ecuador. The majority of information on Las Vegas comes from the type site, Site OGSE-80, the largest known Las Vegas site which was excavated by Stothert during various field seasons between 1971 and 1982. Three phases of Las Vegas have been recognized at this site, Pre-Las Vegas (11,000-10,000 uncal BP), Early Las Vegas (10,000-8,000 uncal BP), and Late Las Vegas (8,000-6,600 uncal BP) (Stothert 1985). Las Vegas represents the transition

from the late Pleistocene into the Holocene up to the introduction of ceramics on the coast with Valdivia at the beginning of the Formative Period. Thus, it represents the transition from mobile hunter-gatherers to more sedentary, unspecialized fisherman and hunter-gatherers, and finally to early agriculture (Raymond 2003; Stothert 1985).

The Formative Period (ca 3500-300 BC)

The Formative Period of Ecuador is generally recognized by the transition from the more mobile way of life practiced during the Paleoindian Period to increased sedentism, reliance on agriculture, and enhanced use and development of ceramics including the widespread production of ceramic figurines. This transition is identified as being earlier, more widespread and more intensive among the coastal people of Ecuador than in other regions of the country. The coastal region has also been much more extensively studied than other regions of Ecuador and its development likely influenced the spread and development of Formative Period lifeways in other regions. The combination of these factors has led to the use of the coastal Formative Period as a model for the Formative Period in the remainder of the country.

Zeidler (2008) has divided the Formative Period along the coast into three subperiods (Early, Middle, and Late) based on the three major associated cultures (Valdivia, Machalilla, and Chorrera respectively). These subperiods vary by culture and, in some cases overlap. The Early Formative (ca 4,500-1500 BC) is characterized by the Valdivia culture that occupied the southern coast of Ecuador around the Gulf of Guayas and the Santa Elena Peninsula. Prior to the development of Valdivia, the Santa Elena peninsula was occupied by the Las Vegas culture, a semisedentary group that practiced subsistence patterns focused on littoral resources and proto-cultigens from which

Valdivia likely developed. The artifact assemblage of Valdivia culture was originally recognized by archaeologists Betty Meggers and Clifford Evans in 1956 at the Valdivia type site (G-31) located in Guayas province. This excavation and subsequent excavations have yielded an assemblage consisting of dense concentrations of pottery, lithics, ceramic figurines, as well as faunal and botanical remains which indicate a reliance on maritime, riverine, and horticulture subsistence practices.

Valdivia sites appear to have been focused along predominate rivers in the area, Excavations at the Valdivia site of Real Alto have revealed evidence of a U-shaped complex of small temporary structures around a central plaza from the earliest stages of the site occupation. During later stages of the occupation, larger more permanent extended family structures were erected around an ellipsoidal plaza with dual mounds, one dedicated to feasting and the other dedicated to burial practices each situated at opposite sides of the plaza (Zeidler 2008). Trade in the form of obsidian procured from Ecuador's primary obsidian deposits in the highlands around the Quito basin and agricultural intensification focused on maize production are documented during this later occupation. Around the same time that the people of Real Alto were developing permanent residences, Valdivia sites begin to appear on isolated islands off the coast indicating the development of water faring vessels. As permanent Valdivia settlements became more rooted, larger ceremonial centers developed with smaller residential secondary settlements surrounding them. Most of these Valdivia sites were ultimately abandoned around 1900 BC when a volcanic eruption from a yet unidentified volcano in the Ecuadorian highlands blanketed the region in volcanic ash (Zeidler 2008).

The Middle Formative subperiod is characterized by the Machalilla cultural occupation (ca 1430-830 BC) concentrated along the Santa Elena Peninsula just north of the Gulf of Guayas. At least as indicated by ceramic style, Machalilla appears to have sprung from the late Valdivia tradition with similar stylistic characteristics exhibited in decoration and form of bowls, ollas, and bottles (Zeidler 2008). The propensity towards the production of ceramic figurines also continues with the Machalilla. Interregional exchange, particularly with the highlands, also continues with the Machalilla culture as evidenced by the appearance of obsidian from the Quito basin and Machalilla-style ceramic vessels along with *Spondylus* (a major product of the Santa Elena peninsula) in the highlands (Zeidler 2008). Machalilla settlements appear to be less dense than previous Valdivia settlements with populations spread across alluvial floodplains in small hamlets that housed extended family members and larger settlements concentrated along the coast rather than large ceremonial centers with associated satellite settlements. Evidence of house structures is still somewhat sparse for the Machalilla culture with only two house floors and no evidence of support structures documented (Zeidler 2008).

The identification of the Late Formative subperiod (ca 1300-300 BC) is based on the development of the Chorrera culture that occupied most of the coastal region and extended up towards the highlands (Zeidler 2008). Chorrera is notable for the wide range of regional variations seen in ceramic styles which focused on effigy bottles with whistling spouts depicting plant and animal figures as well as ceramic figurines. There is little evidence of Chorrera settlement patterns, architecture, or ceremonial structures, though a survey conducted by Zeidler (1995) found the majority (75%) of Chorrera sites occurred in alluvial zones while the remaining sites were found in the uplands, likely the

expansion of settlements outwards from rivers due to dense populations. Chorrera ceremonial centers were located within the midrange of drainages somewhat central to settlements along rivers and in the uplands (Zeidler 2008). Subsistence patterns vary by region but were largely based on the cultivation of maize and different root crops. Evidence of exchange with the highlands around this time has been documented in the form of obsidian from the Quito basin found in Chorrera settlements and marine shells including spondylus found in the highlands. The 450 BC eruption of Pululahua volcano north of Quito blanketed much of the coastal region and its Chorrera inhabitants in volcanic ash ultimately spurring the transition from the Chorrera to the preceding cultures which would come to define the Regional Development Period on the coast (Zeidler 2008).

The Formative Period in the highlands of Ecuador (ca 1800-400 BC) has been divided into four subperiods based on stratigraphic sequencing of ceramic typologies at the type site of Cotocollao in Quito (Lippi 2003). Because many of the archaeologically defined cultures in the highlands are so localized and varied during the Formative Period, Cotocollao is one of the few extensive cultural occupations that can be used to define a consistent and widespread occupation during the Formative Period in the highlands (Zeidler 2008). That being said, the extent of Cotocollao still pales in comparison to the cultures of the coast with most Cotocollao sites found only within or adjacent to Pichincha province. Cotocollao ceramic forms include a variety of bottles, open bowls, and stirrup-spout vessels with a single small looped handle at the base of the spout. The Cotocollao are also known for their production of stone bowls. Cotocollao architecture includes rectilinear structures composed of a series of posts around central beams, a

hearth and storage areas (Zeidler 2008). As with the Chorrera, the end of Cotocollao came when the eruption of Pululahua volcano around 450 BC, which blanketed much of the region in volcanic ash (Lippi 2003).

The Regional Development Period (ca 300 BC-800 AD)

The Regional Development Period of Ecuador is characterized by increased social stratification and interregional exchange predominantly in the form of luxury goods such as gold, silver, marine shell, and, most notably, spondylus. As opposed to the Formative Period, which was dominated by widespread cultural traditions, the cultural advances in the Regional Development Period are demonstrative of increased regional polities and identities (Masucci 2008). A variety of archaeological materials from this period suggest increased sociopolitical complexity, ceremonial activity, and craft specialization. The increase in number of ceramic forms such as bowls, plates, and tripod vessels hints at an increased feasting activities. The appearance of small decorated ceramic spindle whorls and stamps, as well as carved bone and shell objects, become more common indicating textile production and new artistic practices. Elaborate ceramic sculptures, sometimes decorated in a variety of pigments, depict individuals in elaborate headdresses with beaded necklaces, bracelets, and metal nose rings seated on thrones. The variety of regional styles of art and dress represented in these sculptures suggests the development of regional group identities. Most notable, the increased complexity of metallurgy and the intensity of ceramic production have been interpreted as evidence of craft specialization amongst the coastal groups of the Regional Development Period. The appearance of large, low platform mounds which may have served as the location of elite residences or temples during this period is seen as evidence of increased ritual activity and social

hierarchy. In general, the archaeological evidence is discussed as suggesting that Regional Development Period represents the foundations of the first chiefdoms in Ecuador with the formation of political and ritual centers in which platform mounds served as the focus of political and ritual activities. However, some argue that the differences accepted as evidence of stratification are due in fact to the expansion of settlements from the coast inland and the associated change in different resources (Masucci 2008). As with the Ecuadorian Formative, the phenomena that represent the Regional Development Period are more well studied and better understood along the coast of Ecuador than in other regions and, thus, their proliferation on the coast serves as a model for the Regional Development Period in other regions of the country. Though many cultures have been recognized archaeologically during this period, only the La Tolita and Guangala cultures of the coast are relevant to the subject of this thesis and will be discussed in more detail.

The La Tolita culture (ca 600 BC-400 AD) spread from the north coast of Ecuador in Esmeraldas province to the south coast of Colombia. La Tolita culture is known for extensive earthen mound complexes and intricate art style depicted in ceramic sculpture as well as gold, silver, and copper decorations incorporating precious emeralds and obsidian (Masucci 2008). La Tolita sculpture depicts elaborately dressed zoomorphic or anthropomorphic figures in the process of transformation which are interpreted as depictions of elite individuals and mythical characters. The unique and transformative nature of La Tolita art has led to the suggestion that the development and spread of La Tolita represents the proliferation and expansion of a religious cult. The circumstances that led to the end of La Tolita are still somewhat debated but may have been due to

decreased food production or some larger scale environmental event as the decline of La Tolita is similar to, and contemporaneous with, the decline of Guangala to the south (Masucci 2008).

The Guangala culture occupied the southern coast of Ecuador around the Gulf of Guayas and appears to have been the stylistic successor to the earlier Chorrera culture. The Guangala are known for their fine bichrome and polychrome ceramic vessels in the form of bowls and cups indicative of feasting activities. The intensity of production necessary to create such wares as well as certain stylistic similarities suggest that the Guangala relied on the presence of a class of specialized potters found in different centers of production to create and distribute these wares (Masucci 2008). However, unlike contemporaneous groups of the Regional Development Period, archaeologist Maria Masucci (2008) maintains that the Guangala do not exhibit evidence of class differentiation or increased social stratification as documented household and burial goods seem to indicate little difference in material wealth.

The Integration Period (ca 800-1532 AD)

The Integration Period of Ecuador (ca 800-1532 AD) is characterized by increased interregional communication, exchange, and travel which led to the development of large political units with shared identities often understood as chiefdoms. This period is divided into Early Integration and Late Integration phases, a separation punctuated by the 1280 AD eruption of Quilotoa volcano as well as the buildup to the Little Ice Age and the supposed subsequent cultural changes. This thesis will mention only on a few of the Integration Period cultures of Ecuador including the Manteño culture of the coast which extended from Manabí province to the Gulf of Guayas, the Quitu culture which occupied

the area around the Quito basin, as well as various Barbacoan speaking groups of the northern highlands which extended from Quito to Pasto in southern Colombia. The particular Barbacoan speaking groups discussed largely do not extend outside of Ecuador and most notably include the Cara, the Yumbos, and the Cosanga.

The Cara (also referred to as the Caranqui) occupied the region of the northern highlands extending from southern Carchi province in the north to northern Pichincha province in the south and from the eastern cordillera of the Andes mountains to the Intag region in the upper slopes of the montaña in the west. There is an ongoing debate within archaeology over the proper term to use either Cara or Caranqui. The name, Cara originally comes from historian Juan de Velasco's book *Historia del Reino de Quito* which was published in 1789 and lays out the history of the ethnic groups of Ecuador. Velasco's account has been highly criticized in recent decades and is seen as based largely on mythology rather than historical evidence or, in some cases, even outright falsified. Nonetheless, this term has been widely used by archaeologists from Max Uhle (1932) to Stephen Athens (1978) over the last century though Athens acknowledged some of the problems with the use of the term suggesting that it might be best that Cara only be used to identify the ethnohistoric group and not the archaeological culture. The competing term, Caranqui, was used by the so-called father of Ecuadorian archaeology Jacinto Jijón y Caamaño (1914) in the early 1900s and since there has been a more recent push to return to its use by archaeologists such as Tamara Bray (2008), and even Athens (2003) has more recently opted to use the term Caranqui noting that it is also a recognized linguistic culture. The name Caranqui comes from the town of Caranqui located near the colonial-era town of Ibarra and Lake Yahuarcocha in northern Imbabura

province, and was one of the centers of the four major polities that stood against the Inka expansion. This name is composed of two parts, *Cara* potentially referring to the ethnic group and *qui* meaning place or house in the local Barbacoan dialect. Thus, Caranqui literally translates to “place of the Cara”. Because I use Caranqui to more properly refer to the prehistoric independent political entity centered at the town of Caranqui, I prefer to use the term Cara to refer to the entire ethnic group to avoid any confusion.

Much of our historical knowledge of the groups identified as Cara comes from Colonial-era accounts of the Inka conquest of the region. But, as the saying goes, “History is written by the victors.” and these accounts must not be taken without some skepticism. Over thirty Cara chiefdoms were documented by the Spanish after their conquest (Caillavet 2000). Yet of these, four major Cara polities dominated the Cara region at the time of the Inka conquest, and the extent of influence of each group within the region or on each other is not well known, although they are generally seen as emanating outward from their political centers, which are now the sites of contemporary towns that bear the same name. The first group encountered by the Inka during their campaign northward was the Cochasquí whose dominion extended from Guayllabamba in the south to the peak of Mojanda volcano in the north. It should be mentioned, however, that historically the adjacent entities of Quito, Otavalo, and Cayambe have attempted to make claims over the region of Cochasquí (Caillavet 2000). Nonetheless, the Cochasquí are described in historic documents as having some level of autonomy and, in some, even a Queen at the time of the Inka conquest. The political center of the Cochasquí was an extensive pyramid complex located on the southern flank of Mojanda volcano, now a designated archaeological park near the small town of the same name.

The second group was the Cayambe located at the foot of Cayambe volcano which is now a large town of some 30,000 inhabitants that shares the same name. The next group were the Otavalo whose political center has alternately been recorded as Otavalo or Sarance (written as Çarance in some of the earliest documents) prior to the Inka conquest (Caillavet 2000). In either case their political center would have been located along the banks of Lake San Pablo near the contemporary town of Otavalo in Imbabura province. Caranqui was the final political entity encountered by the Inka on their northward progression.

Archaeologically, the Cara culture is identified by a shared artistic tradition most evident in ceramic stylistic attributes and, notably, in extensive earthen mound construction (Athens 1980; Bray 2008). The earliest Cara mounds constructed during the Early Integration Period are smaller, hemispherical burial mounds which overly shallow burial shafts. During the Late Integration Period, the construction of hemispherical burial mounds ceases in favor of much larger quadrangular pyramids many of which exhibit extended entry ramps the longest of which measures three hundred meters in length. The transition from the Early to Late Integration Period is marked by the 1280 AD eruption of Quilotoa volcano which exploded with an estimated Volcanic Explosivity Index (VEI) of 6 and blanketed much of the country in volcanic ash.

Great political and social upheaval came during the Integration Period with the Inka invasion of Ecuador, which depending on the source, begins any time between 1450 and 1500 AD and lasted until the Spanish conquest in 1532 AD. During the Inka conquest of Ecuador, the Inka emperor Thupa Inka Yupanki encountered some of the fiercest resistance to their advance from the Cara. The complete conquest and

consolidation would not come until the rein of Thupa Inka's successor Wayna Qhapaq. The traditional chronology for the Inka developed by John Rowe (1945) and based largely on the work of Cabello de Balboa (1945[1586]), suggests that the expansion of the Inka state was relatively rapid and the war in northern Ecuador relatively brief. Accounts of the war between the Inka and the Cara are somewhat variable with some Spanish chroniclers referring to the conflict as a resistance while others refer to it as a rebellion. The implication for historians and archaeologists being that, if it was a resistance, then the Cara had not yet been conquered by the Inka when confronted by Wayna Qhapaq and were resisting the advance of the empire. But, if it was a rebellion, then the Cara had already been conquered by Thupa Inka and were rising up against the invaders. Based on the original chronology, it has been suggested that there was a ten-year stalemate between the Inka and the Cara. More recent interpretations supported by archaeological research and absolute dating techniques have challenged this short chronological sequence suggesting that the Inka entrance into Ecuador may have been up to 20 years earlier than previously suggested (Ogburn 2012). While such a disagreement over a short period might seem petty to some, it is crucial for determining the chronology of the imperial advance and the initiation of post-conquest social restructuring and imperial-style architectural monuments in the north. In either case, it is agreed that there was a stalemate between the Cara and the Inka with the front marked by the Guayllabamba river valley just north of Quito.

The stalemate was finally ended when emperor Wayna Qhapaq crossed the Guayllabamba and through brute force, and the loss of many lives, sequentially conquered Cochasquí, Cayambe, Otavalo, and Caranqui. The final battle between the

Inka and Cara came at Laguna Yahuarcocha where the exhausted and surrounded Cara forces made their final stand and were slaughtered in the thousands giving the lake its ominous name, which in Quechua translates to “Lake of Blood” (Sarmiento de Gamboa 1907[1572]).

The Inka occupation of the northern Ecuadorian highlands brought about many changes. The Inka famously instituted a system of management throughout the empire known as *mitma* in which conquered groups were relocated to different portions of the empire separating them from their allies and sacred landscapes or placing allies of the Inka close to particularly troublesome groups. The result of this system today is that many communities throughout the former empire are ethnically and culturally foreign from the pre-Inka ethnic groups. The subsequent social reorganization instituted by the Spanish immediately after the Inka only further compounds this problem. Thus, it can often be difficult to tease apart original cultural traditions from those instituted after one of these conquests. Though Inka resistance to the Spanish continued for years after their arrival, the end of the Inka occupation in Ecuador was solidified in 1533 when Benalcazar’s troops, along with numerous indigenous Cañari fighters fed up with Inka rule, defeated the Inka general Rumiñawi at a battle near Riobamba forcing the Inka into a retreat from which they would never recover (Velasco 1841 [1789]).

V. MYTHS, VOLCANISM, AND VOLCANIC STUDIES

The purpose of this chapter is to orient our perception of volcanos in Ecuador within the context of culture, history, geology, and archaeology. As such, the following outlines some of the mythology and historical mentions of volcanos as well as some of the evidence for the environmental relationship between human populations and their volcanic environment. Information regarding climate, geologic changes to the landscape, obsidian sources, and the application of tephrochronology is discussed, as well as some of the evidence for regional forced migration and abandonment.

Volcanos in Ecuador

Though the terms active and inactive are often used when discussing volcanos, these terms often lack secure definitions and volcanos that have lain dormant for thousands of years can suddenly rumble back to life. Instead, whether a volcano has had a Holocene-age eruption as a measure of recent volcanic activity is a much more accurate predictor of potential future activity. There are over thirty prominent volcanos in the Ecuadorian highlands and there is evidence that at least fifteen of these have had eruptions during the Holocene (Hall 1977). The portion of the Interandean Valley from Tungurahua province to the Colombian border is known as the “Avenue of the Volcanos” due to the presence of numerous prominent peaks to the right and left as one travels through the valley (Figure 2).

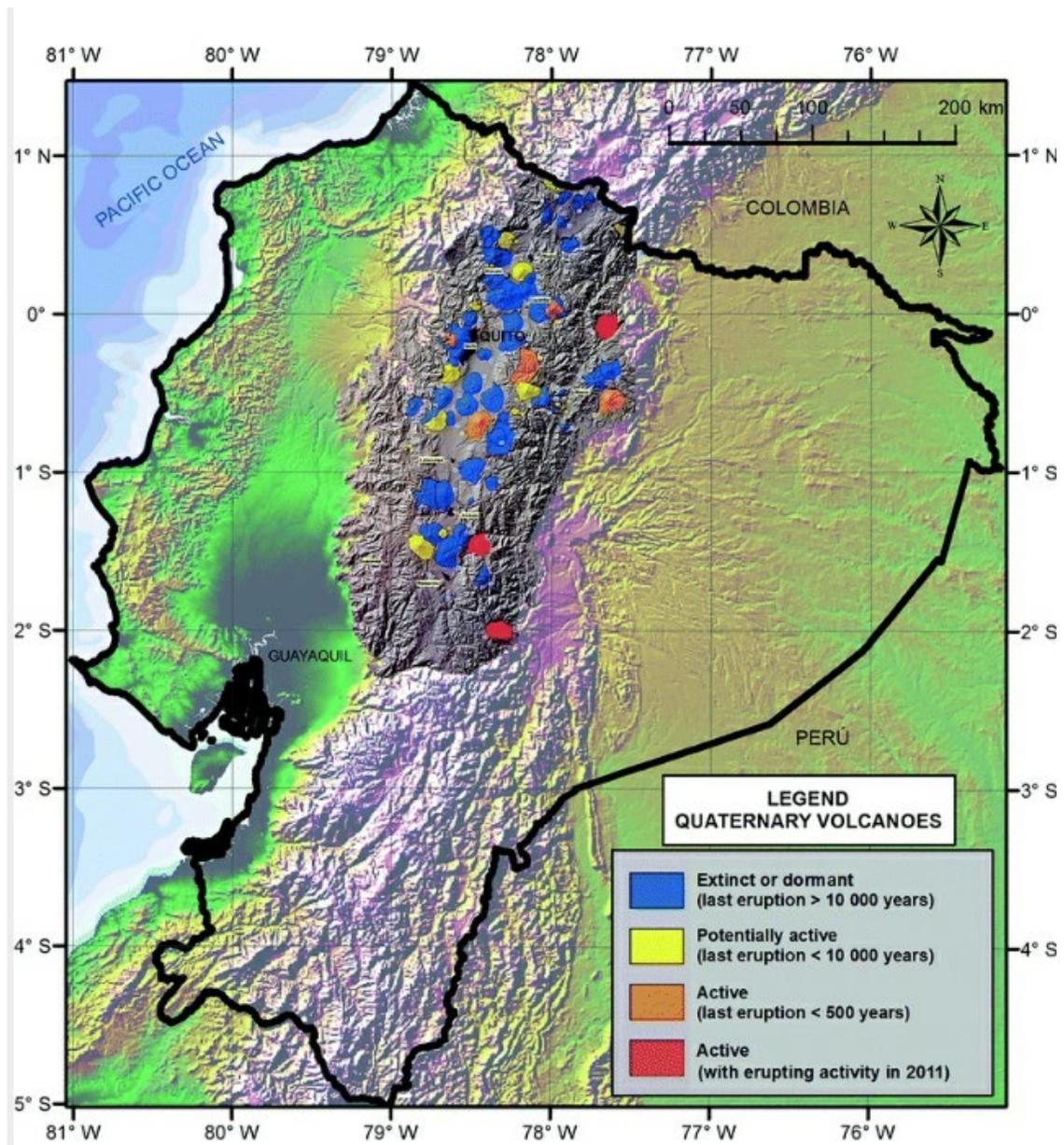


Figure 2: Volcanos of the Interandean Valley (from Espinosa et al. 2018).

There are many reasons that ancient people may have feared and venerated the high peaks and volcanos of Ecuador. A great deal of mundane and spectacular phenomena are associated with volcanos and high elevation peaks. Even at the equator, the highest peaks over 4,900 meters are snowcapped year-round and the frozen glaciers of the larger peaks provide a near constant source of life-giving water to the surrounding landscape. Due to uplift and magmatic upwelling, the peaks of greatest size are the

volcanos (Espinosa et al. 2018). The rising sun and the setting sun especially turn the white peaks a brilliant orange and gold hue. At high elevations with few obstacles to obscure light and increased moisture, optical meteorological phenomena such as parhelia, atmospheric refraction, and halos can make being in such places a bizarre and otherworldly experience. Such phenomena were experienced by the mystified members of the French Geodesic Expedition (Juan and Ulloa 1748). The tallest of the peaks produce their own distinct weather patterns and the orographic effect caused by them leads to the development of rain and snowfall around the summit even when there is a significant drought across the rest of the landscape. The storms that do cross over the frozen peaks can bring rain as well as snow and hail as they pass over the towns and farms below. During eruptive episodes even minor eruptive events can melt the snow and glaciers near the vent causing devastating mudflows. The immense quantity of mud and debris caught in these flows surges out like a flash flood moving at recorded speeds up to 30 kilometers an hour and burying entire towns meters deep (Whymper 1892).

Volcanic ash and gasses released from the eruptive vents can, even in minor amounts, when inhaled, consumed, or imbibed in liquid can increase toxicity and adversely affect long term health (Gudmundsson 2011; Horwell and Baxter 2006). The ash released from the volcano in immense plumes produces cloud-like effects blocking the sun, reducing temperatures, and covering plants blocking both respiration and photosynthesis. At high elevations, the lower atmospheric density allows heat to escape the ground and the air much more quickly. Thus, the lack of sunlight can cause significant cooling. The chemical change in pH brought about by the addition of volcanic ash to the soils kills those plants that might have otherwise survived the suffocating

coverage and darkness (Isaacson 1987). These ash particles also serve as an aggregate for atmospheric moisture causing sludge-like rain in some cases. Electrical discharge generated by the friction between ash particles and conducted by water vapor released from the eruptive vent produce a spectacular display of bolts of lightning within the clouds of volcanic ash emanating from the vent (McNutt and Williams 2010).

The release of super-heated gasses during explosive eruptive events produce pyroclastic flows launching clastic materials sometimes tens of kilometers from the event. These clastic materials ejected from the vent can emerge glowing bright white or red. The mass of the clastic materials within the pyroclastic surges pushes the super-heated gases forward even outside the range of the clastic materials, which can instantly kill any unfortunate enough to be caught in their path (Mastrolorenzo et al. 2010). These heated gases can kill even microbiotic organisms that are the primary cause of postmortem decay. If humans or other animals are then quickly buried by volcanic ash, they are preserved as in the case of the iconic casts from Pompeii (Guarino et al. 2005). Though no examples as striking as Pompeii have been recorded in Ecuador, ancient people may have stumbled across and recognized preserved casts. Mineral replacement by ash particles can quickly produce fossilization and has been attributed to the creation of vast petrified forests in other regions of the world. Even outside of explosive eruptive events, the unexpected release of poisonous gas from the vents can silently kill humans or livestock that are unaware. And, of course, lava released from the vents can surge down slope covering everything in its path and igniting nearby vegetation. The eruptions of volcanos also produce earthquakes through caldera collapse, shear fracturing of tectonic faults, and the explosive release of gas (Schick 1981).

Though those of us detached from volcanic landscapes generally consider the rare explosive eruptive events that can eject lava or super-heated clastics, many of the more commonly occurring moderate eruptive and mundane natural events surrounding volcanos are associated with water. Given the number of phenomena that generate rain, snow, hail, clouds, floods, or lightning associated with the volcanos, it's unsurprising that ancient people and the farmers of today dependent on the meltwaters from glaciers to feed their crops might associate these imposing natural features with water more so than lava or fire. I have several times heard farmers refer to the mudflows produced by volcanic eruptions as "floods" rather than lahars. Further, the effect of falling white volcanic ash and white pumice even resembles the appearance of snow and hail. There may have been some association with the phenomena as rain and ice were both seen as being controlled largely by the volcanos (Caillavet 2000; Maldonado 1897 [1582]). Thus, when considering the range of phenomena that volcanos as gods might retain power over, it should be thought of much more broadly than simply power over fire or explosive eruptions.

Mythology of Volcanos in Ecuador

Stories regarding the veneration of high mountain peaks by the native inhabitants of Ecuador extend as far back as its history and highlight their anthropomorphic properties, gender, interpersonal relationships, prophetic natures, and control over natural phenomenon. The volcanos may also be central to concepts of group identity. Many prehistoric ethnic groups and even modern-day towns, *cantóns*, and provinces share their names with the largest and most important nearby peaks. Ancient stories of the

interactions and relationships between volcanos may hint at ancient conceived notions of relationships and interactions of said groups.

The early writings of Paz Maldonado (1897 [1582]) discuss the relationship that the Puruhá had with Chimborazo volcano. Chimborazo volcano, in Tungurahua Province, is the largest volcano in Ecuador and was highly venerated in ancient times as the locals of the region thought themselves descended from it. Chimborazo was said to be male and is the husband of the nearby Tungurahua volcano, which was said to be female. A similar story provided by a guide to Alexander von Humboldt (1883 [1862]) takes this characterization a bit farther stating that the two often have tiffs during which Tungurahua blows smoke into the face of Chimborazo. The two peaks are connected by an extensive underground tunnel and often play cards together. In 2017 I was told an extension of this story in which Tungurahua and El Altar to the south were once lovers. When Tungurahua withdrew her affections and placed them with Chimborazo, El Altar, in a fit of rage, blew its top forming the volcanic crater lake which now exists in place of its summit. Maldonado recounts that a great herd of llamas lived along the slopes of Chimborazo, which were said to have been brought as an offering by the Inka and were regarded as sacred by the locals. Upon hearing of these sacred herds, the Spanish set forth to wipe them out and forced the locals to participate in the slaughter. Shortly after the deed was done, the locals found that a great frost had descended on their crops freezing them solid, which they attributed to the displeasure of the volcano itself. Thus, these accounts suggests that the volcanos are active players on the landscape and that their eruptive events have mythological explanations for the people that venerate them. The account provided by Maldonado also highlights the association between the snowcapped

volcanos and frost or freezing temperatures and indicates that prevention of crop loss due to frost is partially dependent on appeasing the volcanos.

Another account of El Altar provided by Alexander von Humboldt in a letter to his brother dated November 25, 1802 describes how Humboldt met Leandro Zapla living in Likan who claimed to be a prince of the Puruhá and held manuscripts originally written in Puruhá, but translated into Spanish which described their history (Humboldt 1905 [1802]). The documents explain how the Puruhá once held dominion over all of the central highlands and that Puruhá was spoken even in Quito until the arrival of the Inka. Zapla claimed that also within this document was a description of the eruption of El Altar which took place 14 years before the arrival of the Inka and that this eruption lasted for eight years casting the region into darkness. Thus, when the Inka did arrive, the region was largely destitute. Volcanologist Patricia Mothes has assured me that there is no known evidence of a Holocene-age eruption of El Altar, but a lesser-known and less grandiose volcano is being investigated as a possible source of the late prehistoric eruption (personal communication 2018). As to the extent of the kingdom of the Puruhá, there is no archaeological or linguistic evidence to support this claim either. The story provided by Humboldt hints at the way in which histories could be augmented to extend ancient claims over territory, but also to incorporate more sacred features of the landscape in dramatic historical events in a way that is more conducive to the mythology. That being said, if there truly was any eruption 14 years before the arrival of the Inka, good radiocarbon dates from this eruption may help determine whether the Inka arrival was as late as 1500 AD as some have claimed or as early as 1450 AD as suggested by others.

In the northern highlands, a myth exists which outlines a relationship very similar to the Chimborazo/Tungurahua/El Altar myth. Caillavet (2000) writes that in this version of the myth, it is said that volcano Imbabura, above the town of Otavalo, is the father of the Otavaleño ethnic group and the nearby Cotacachi is his wife. In 2018, I was told a version of this story in which Cayambe volcano to the south, like El Altar in the Puruá myth, had affections for Cotacachi and, unable to win her love over Imbabura, erupted in rage. Climatic changes around the town of Otavalo are attributed to the state of the relationship between the husband and wife volcanos. Natives interpret the foam of the waves on Lago San Pablo at the base of the volcano or small clouds as the messages being transmitted between the two. Thus, interpretations of these minute natural phenomena can serve as predictors of broader climatic conditions that may result from the mythical relationship between the husband and wife. Should an individual want to ensure rain or a good harvest, sacrifices of live chickens are made to Imbabura to win its favor. This example underscores once again the powers attributed to the volcanos over climate and weather, especially those related to crops.

Historic accounts of ancient volcanic eruptions also suggest that volcanos have a prophetic nature especially in regard to political upheaval. Cotopaxi is said to have erupted prior to the arrival of the Spanish. The jagged series of peaks located on the eastern flank of Cotopaxi comprise a feature known historically as the “Head of the Inka” which has been described in local lore as a massive volcanic bomb which was once the summit of the volcano. Juan de Velasco (1789) claims that this feature was ejected from the volcano in 1532 AD, an event that foretold the arrival of the Spanish and the defeat of the Inka. Alexander von Humboldt (1850) suggests that this story was still maintained by

some of the locals during his visit in the early 1800s. It is unlikely that such a massive natural feature situated atop a steep slope could be the result of a volcanic bomb. Instead, it seems more likely that the appearance of this jagged peak, as in the case of the El Altar eruption recounted by Humboldt, was reinterpreted to conform with a mythological explanation of the volcanic event.

The above myths paint a picture of volcanos that play very active roles in the lives of the native people of Ecuador. Careful observance and appeasement of volcanos and the meteorological events surrounding them is paramount to maintaining a good climatological stasis. Severe meteorological phenomenon which can affect crops are the result of the displeasure of the volcanos either with humans or other volcanos. The fact that some ethnic groups trace their descent to the prominent nearby volcanos or share their name with these volcanos indicates the strong role these sacred features of the landscape play in the development of ethnic identity. Hechler (2014) has suggested that the mythological relationships between the volcanos may hint at events related to interactions between ethnic groups. Thus, the marriage between two volcanos may signify some sort of alliance between the groups that identify with these volcanos while spurned lovers may suggest a conflict, disagreement, or broken alliance between ethnic groups.

Evidence of Climate

This section presents some of the geoarchaeological studies of climatic fluctuations through Ecuadorian prehistory. Various forms of evidence have been collected from a number of sources including sedimentary analysis of high-altitude glaciers, lake core

sediments, and bog cores. The majority of these studies focus on climate fluctuations during the last thousand years.

Glaciation. Heine (2011) looked at evidence of the extent of permafrost on high-altitude peaks around the Quito basin as evidence of glaciation during the Quaternary. Heine presents a synthesis of ten years of research on stratified deposits dated through tephrochronology and radiocarbon samples. Evidence of permafrost was identified via a method outlined by Francou (1990) which suggests that grain-size sorting in grèzes-litées type deposits along with solifluction can be used as evidence of needle ice, frost creep, and gelifluction. Today, these types of deposits are found only above 4,800 meters, so deposits below this altitude represent past permafrost extents. During the Pleistocene before 30 kya, permafrost extents correspond to temperatures four to five degrees Celsius cooler than current temperatures, which coincides with evidence from marine core sediments in the Pacific suggesting greater aridity. Due to the influence that Pacific Ocean and Amazonian climatic conditions have on moisture regimes in the Andes, this suggests that both the Pacific coast and the Amazon basin were more arid during this time period. The maximum glacial extent in the Pleistocene was reached around 30 kya when glaciers began receding, a full nine thousand years before the global maximum glacial extent as inferred from marine isotopes. Marine sediments from coastal Ecuador suggest La Niña-like aridity and a northward shift of the Intertropical Convergence Zone rather than increased temperatures was the primary cause of this deglaciation. The aridity stimulated deglaciation continues through the first half of the Younger Dryas until an increase in humidity once again initiates glacial advance.

During the Holocene between 8.9 and 3.3 kya, increased warming halts the advance of glaciers until the Neoglacial/Little Ice Age. Though Heine could find little sedimentological evidence of glacial advance during the Neoglacial/Little Ice Age, he notes that glacial records in Colombia and Venezuela suggest a maximum glacial extent between 1740 and 1800. Lake core sediments from Peru show possible glacial readvance around 5000 years BP conforming with global patterns. Minor readvances occurred later during the Holocene. Globally, the Neoglacial begins around 5000 BP and the Little Ice Age, the most intensive portion of the Neoglacial, lasted from 1500 to 1900 AD. Historic records from Ecuador indicate that the greatest extent of the snowline for mountain peaks over 5700 meters was sometime around 1720 AD and around 1830 AD for those with summits below 5400 meters. Comparisons with the global climatological record indicate climatic fluctuations in Ecuador may have been influenced to a greater extent by the Younger Dryas Stadial and to a lesser extent by the Antarctic Cold Reversal.

The Sucus Bog Core. Ledru et al. (2013) conducted a sedimentary and palynological analysis of the Sucus bog at Papallacta 3,800 meters above sea level on the Cordillera Real west of Quito. A nine-meter-deep core was removed from the bog and the first two meters were assessed as representative evidence of climatic changes for the last 1,100 years. This uppermost portion of the core was composed of peat interspersed by three tephra layers (M1-M3). Radiocarbon samples from within the peat layers indicated four periods separated by these ash layers spanning from 850 to 1250 AD, 1250 to 1550 AD, 1550 to ~1650 AD, ~1650 to 1800 AD. Prior to 1250 AD, pollen frequencies indicate a warm humid environment with a slight dry interval between 990 and 1090 AD as well as two cold periods at ~1030 AD and ~1270 AD. The period between 1250 and

1550 AD is characterized by less moisture as evidenced pollen frequencies as well as lower convective activity and represents the driest interval within the core sample. Moist conditions return to the region between 1550 and approximately 1650 AD as indicated by increased species variation and tree frequencies, though a brief cold, dry episode occurred around 1550 AD at the initiation of this sequence. The following period from approximately 1650 AD until 1800 AD exhibits evidence of a cooler wetter climate on average with a significant cold and dry period between 1750 and 1800.

The 1280 AD eruption of Quilotoa volcano almost perfectly coincides with the initiation of the significant dry period between 1250 AD and 1550 AD as well as the cold period around 1270 AD seen in the Sucus bog core. The drier climatic conditions beginning around 1250 AD may be due to broad scale global trends. In 1257 AD, Samalas volcano in Sumatra erupts with a VEI of 7 spreading volcanic ash which can be found in polar ice cores (Lavigne et al. 2013). This colossal eruption was followed within a 50-year period by three other colossal eruptions in the tropics which created cool summers in the arctic allowing for ice growth (Miller et al. 2012; Slawinska and Robock 2017; Zhong et al. 2011). Climate models suggest that colossal volcanic eruptions spaced approximately 10 years apart would result in a self-sustaining sea-ice/ocean feedback suppressing summer temperatures for years ultimately leading to the development of the Little Ice Age (Miller et al. 2012). Though yet to be confirmed, considering the size of its eruption, its location on the equator and date of its eruption, Quilotoa is likely one, if not the next, of these colossal eruptions. Thus, the dry period documented in the Sucus bog core may be due in part to global trends, while the cold period at approximately 1270 AD may be attributed to the effects of the Quilotoa eruption itself.

The Huarmicocha Lake Core. High elevation lake cores from locations within the Interandean Valley can represent climatic changes in both the Pacific and Atlantic oceans due to the influence these systems have on highland moisture regimes. In one particularly notable study due to its central location within the highlands, Riedinger (1993) examined the sedimentation and fossil diatoms from a lake core sample taken from Huarmicocha lake in the Mojanda volcanic crater just north of Quito. The sequence produced from these cores extends back approximately 900 years (875 uncal BP \pm 65). The sediment sequence present within the core was composed primarily of gyttja, laminated sand, and dark sand overlying clay and volcanic ash. Laminated sand in the upper portion of the sample was interpreted as being the result of wash during refilling events after the lake had dried while gyttja represents sedimentary deposition during periods when the lake was drier but filled with shallow water indicating a recent refilling of the lake. Diatom species diversity increased in layers of gyttja and decreased in layers of sand supporting this interpretation. A thick dark layer of sand near the base of the core was suggested to be collapse of dry lake sand which occurred during a significant drying event. Thus, several distinct periods of climatic change are represented by sediments within the core sample with high water levels represented at the base of the core column.

The Huarmicocha sample presents evidence of two distinct high-water periods interspersed by two dry periods. Sediments at the base of the core indicate a high water level was reached in the lake around 875 BP. High concentrations of sand and clay just above the base suggest the initiation of drier conditions in which the lake may have dried completely between 875 and 550 BP. Between 550 and 432 BP, high concentrations of diatoms, organic matter, and carbon content suggest cooler and wetter conditions likely

associated with the full onset of the Little Ice Age. The laminated sand within the upper portion of the core column indicate increased seasonal variability between 500 and 140 BP. The high organic content of the sediments in the upper portion of the column may be the result of anthropogenic disturbance such as the burning of fields for nearby agriculture. The initial drying event represented within the Huarmicocha sample likely corresponds to the drier climatic conditions which occur after the 1280 AD eruption of Quilotoa volcano.

Volcanism and Volcanic Studies

Ecuador is one of the most volcanically active countries on earth and it is impossible to conduct archaeology in the country without considering at least the indirect effects of volcanism. Though the terms active and inactive are often used when discussing volcanos, these terms often lack secure definitions and volcanos that have lain dormant for thousands of years can suddenly rumble back to life. Instead, whether a volcano has had a Holocene-age eruption as a measure of recent volcanic activity is a much more accurate predictor of potential future activity. There are over thirty prominent volcanos in the Ecuadorian highlands with eruptions during the Quaternary and there is evidence that fifteen of these have had eruptions during the Holocene (Hall 1977). Most of these volcanos are located on the Cordillera Real and are stratovolcanos, known to produce massive and unexpected eruptions (Espinosa et al. 2018; Isaacson 1987). The portion of the Interandean Valley in the northern highlands from Tungurahua province to the Colombian border is known as the “Avenue of the Volcanos” due to the presence of numerous prominent peaks to the right and left as one travels through the valley.

It can easily be argued that the first scientific assessment of the volcanos in Ecuador in the post-Enlightenment sense was conducted by Alexander von Humboldt during his journey through the region in the early 1800s. Humboldt documented the apparent geologic evidence of volcanic eruptions and cone formations eventually producing several accounts with detailed drawings including *Volcans des Cordillères de Quito et du Mexique, pour servir aux œuvres de Humboldt et spécialement aux mélanges de géologie et de physique générale* (1864) and *Vues des Cordillères et monuments des peuples indigènes de l'Amérique* (1810). The descriptions and accounts provided in these works are still used by volcanologists today.

In addition to the geologic formations, mineral compositions, and formation processes, Humboldt also recorded myths regarding volcanos and volcanic eruptions as well as ethnographic accounts which highlight the relationship between the local inhabitants and the volcanos. One notable account provided in Humboldt's work (1883 [1862]) states how hundreds of years before the members of the French Geodesic Expedition used their surveying equipment to measure the heights of Ecuador's tallest peaks, the inhabitants of the region knew which of the peaks were the largest. Humboldt writes that this was done using approximations from the lower limit of the snow line. Near the equator, the snowlines on the volcanos are at near constant levels and at a relatively even level compared to locations further into the northern and southern hemispheres. The distance from the snowline to the peak can thus be used as a reliable datum to measure and compare the height of the volcanos.

More recent advances in volcanology in Ecuador since the 1970s have been largely driven by volcanologists Patricia Mothes and Minard Hall who founded

Ecuador's Instituto Geofísico. Mothes and Hall have produced numerous works dating volcanic eruptions and measuring their areas of impacts (Hall 1977; Hall and Mothes 1994; Mothes and Hall 2008). Because past volcanic processes are indicative of possible future events, the study of volcanism and volcanic eruptions in Ecuador is largely driven by efforts to predict and protect against impacts to infrastructure and extant populations. Today, the Instituto Geofísico monitors volcanic and tectonic activity primarily for hazard management.

Tephrochronology

Tephrochronology is particularly important and well-studied in the archaeology of the northern Ecuadorian highlands. Because each volcanic eruption produces volcanic ash with a unique chemical composition, once the diagnostic components of an eruption are identified, ashfall can be traced back to a particular eruption at a particular time.

Catastrophic volcanic eruptions produce widespread ashfall and the subsequent movement of populations and cultural changes induced by these eruptions are used by archaeologists both wittingly and unwittingly to mark different cultural periods. The ashfall from these large eruptions then serves as important chronostratigraphic markers for these different time periods and, as such, their eruptions and distributions have been fairly well studied and documented (Hall 1977; Hall and Mothes 1994, 1998). The Volcanic Explosivity Index (VEI) is a method of estimating the impact of a volcanic eruption in a way similar to the Richter Scale and was suggested by Newhall and Self (1982). The scale is divided into nine categories (0-8) determined primarily by the volume of ejecta produced during the eruption which increases exponentially within each category. Generally, volcanos which produce a greater volume of ejecta have wider

ashfall distributions. Thus, this metric can be used as a rough estimate for the level of impacts with higher VEI eruptions corresponding to more widespread area of impacts especially in instances in which more exact maps of ashfall distributions have not been created.

Abandonment and Migration

The aspects of these post-eruption abandonments and migrations are also frequently discussed within Ecuadorian archaeological literature. There is, however, a clear evidentiary bias favoring abandonment over migration in archaeology as abandonment can be immediately suggested from the presence of volcanic ash overlying the final occupation in an archaeological context. Migration must be more broadly inferred using a variety of evidence from various locations and sources. Volcanic ashfall can devastate landscapes not only through the suffocating coverage, but also through the acidic chemicals which are released from ash particles as they cool destroying ecosystems (Isaacson 1987). The increased acidity of the soil leaves the landscape largely barren until diagenetic processes return the soil to an acceptable pH for plant life. Isaacson (1987) suggested potential levels of impacts on human populations in Ecuador using comparative evidence from Iceland where fresh volcanic ashfall between 10- and 15-centimeters-thick results in abandonment between one and five years while fresh ashfall greater than 15 centimeters thick can result in multiple decades of abandonment. Ashfall 50-centimeters-thick or more results in a significant increase in the necessary recovery time for the effected region. Depositional processes generally result in approximately 30% compaction of ash layers over time which must be considered when examining ashfalls in archaeological contexts (Patricia Mothes personal communication 2018).

Periods of abandonment are likely less extensive in tropical regions where increased rainfall allows volcanic ash to be more quickly processed into the soil (Isaacson 1987; Knapp and Mothes 1998).

Obsidian Sources

Obsidian forms on the margins of silica-dense rhyolitic lava flows and was particularly important to the people of ancient Ecuador due to the lack of other suitable lithic materials save basalt. The vast majority of known viable obsidian sources in Ecuador are located east of the Quito basin on the Cordillera Real between Antisana volcano in the south and Cayambe volcano in the north (Bigazzi et al. 1992; Burger et al. 1994). It may be no surprise then that the earliest evidence of human occupation in Ecuador from the El Inga culture comes from just west of these major sources near Ilaló. Obsidian from the highlands begins to appear on the coast during the Formative Period and becomes widely distributed during the Regional Development Period. For reasons still poorly understood, obsidian use in the Integration Period declines until the arrival of the Inka.

The largest and most well studied obsidian sources in Ecuador are the Mullumica and Yanaurcu-Quiscatola sources. Yanaurcu-Quiscatola, which is a smoky gray obsidian, appears to have been largely exploited between 3447 BC and 979 AD, while Mullumica was exploited primarily between 2690 BC and 1580 AD. Evidence of ancient mining and procurement practices exist at both of these sources (Bigazzi et al. 1992). In addition to these major identified sources, evidence exists of other minor sources in the same region of the Cordillera Real which may have been utilized as well including the Callejones, Yurac Paccha, Rodeo Corrales, and Potrerillos sources (Bellot-Gurlet et al. 2008). To the south, Cotopaxi volcano may serve as another potential source while, to the north, it has

been suggested that Mojanda volcano may be yet another poorly documented obsidian source (Bellot-Gurlet et al. 2008; Wagner 1978).

Though often called Mojanda, the large volcano on the northern edge of the Quito basin is actually a volcanic complex composed of Fuya-Fuya volcano to the west and Mojanda volcano to the east. Bellot-Gurlet et al. (2008) collected three obsidian samples from Mojanda, though the exact location from which these samples were collected is unclear. X-ray fluorescence of these samples and numerous samples from other sources around the Quito basin found that the Mojanda source and the Yanaurcu-Quiscatola sources were almost indistinguishable. Thus, it's possible that obsidian attributed to the much more widely recognized and well-studied Yanaurcu-Quiscatola source, might actually come from the much more poorly recognized Mojanda source. The lower Fuya-Fuya flows are documented as being high-silica andesitic to rhyolitic flows (Robin et al. 2008) and thus may be conducive to obsidian formation.

Eruptions as Drivers of Change and Chronostratigraphic Markers

This discussion details three particularly important volcanos with eruptions which caused significant impacts on the people of the northern Ecuadorian highlands as well as in other regions of the country. These three eruptions coincide with, if not helped cause, major cultural shifts associated with the transitions between recognized cultural periods. As such, the examination of these eruptions is particularly important for understanding the drivers behind these transitions as well as recognizing the chronostratigraphic markers which can denote these periods in the archaeological record.

Pululahua Volcano. The earliest eruptions amongst these three volcanos was produced by Pululahua volcano, located on the cordillera occidental just north of Quito.

There is evidence of two particularly large volcanic eruptions of Pululahua volcano, one dated to approximately 690 BC with an estimated VEI of 5 and another dated to approximately 450 BC with an estimated VEI of 4. The 450 BC eruption especially coincides with cultural changes in the northern highlands and along the northwest coast of Ecuador that mark the end of the Formative Period and the beginning of the Regional Development Period (Figueroa Arciniegas 2015; Isaacson and Zeidler 1998).

The ashfall distribution of this Pululahua eruption has been described as somewhat unique due to its occurrence within approximately still atmospheric conditions producing a circular proximal and Plinian ashfall distribution pattern (Volentik et al. 2010). Identified distal ashfall deposits from this eruption suggests a slight east to west and north to south gradient extending all the way to the coast with levels of impact decreasing with distance from the volcano (Isaacson and Zeidler 1998). On the northern coast, this ashfall put an end to the Chorrera culture and paved the way for the Manteño culture to the south to become the dominant coastal polity after the initiation of the Regional Development Period (Isaacson and Zeidler 1998). In the highlands, the eruption forced the abandonment of Cotacollao sites around Quito allowing for the later and more variable shaft tomb cultures of the Regional Development Period to take root (Isaacson and Zeidler 1998).

Quilotoa Volcano. Possibly the most frequently discussed volcanic eruption in Ecuadorian archaeological literature is the 1280 AD eruption of Quilotoa due to the intensity of this eruption and the wide distribution of its effects. The majority of volcanological studies of Quilotoa volcano have been carried out by Patricia Mothes and Minard Hall (Hall and Mothes 2008; Mothes and Hall 1991, 1997, 1998). Quilotoa

volcano is a massive crater lake measuring between 2.4 and 2.8 kilometers across located on the Cordillera Occidental in southern Cotopaxi province. The 1280 AD eruption of Quilotoa measured a VEI of 6 and blanketed approximately 40,000 square kilometers with ashfall which can be found in most regions of the country (**Figure 3**) (Hall and Mothes 2008; Di Muro et al. 2008). The widespread distribution of this volcanic ash in Ecuador created a chronostratigraphic marker which is used in the archaeology throughout most of the country.

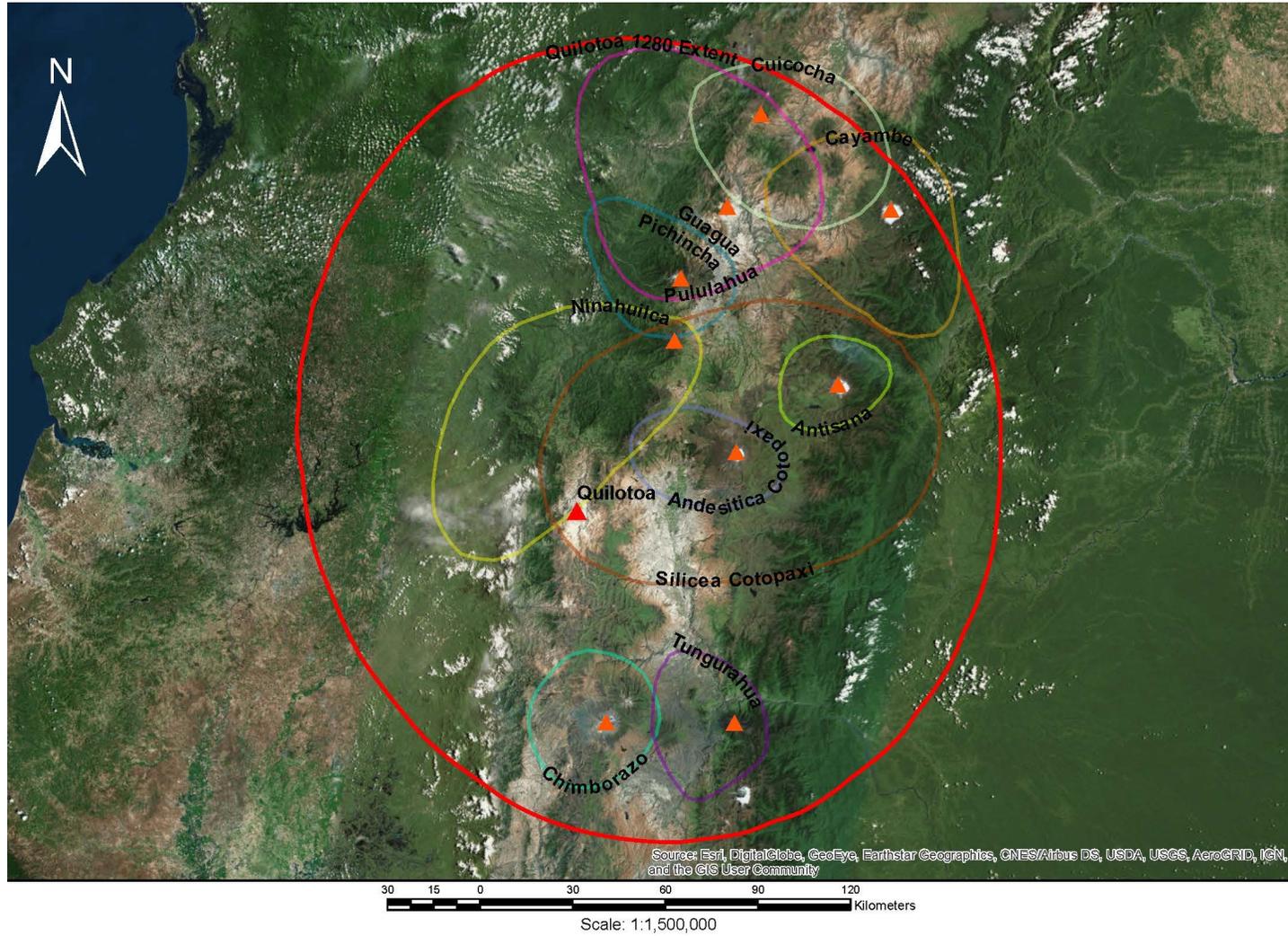


Figure 3: The 1280 AD Quilotoa ashfall extent compared to other ashfall extents (adapted from Hall and Mothes 1994 and Mothes and Hall 2008).

In the northern highlands amongst the mound and pyramid building Cara culture, the presence of Quilotoa ashfall is associated with a cultural change which marks the transition from the Early Integration Period to the Late Integration Period (Mothes and Hall 1998). During the Early Integration Period, the Cara people of Pichincha and Imbabura provinces were known for their hemispherical burial mounds and their extensive raised field agricultural systems known as *camellones* which covered hundreds perhaps even thousands of hectares (Knapp and Mothes 1998). After this eruption, raised field agriculture all but ceased and the Cara forwent building hemispherical earthen burial mounds in favor of building large truncated pyramids.

Prior to the documentation and dating of this eruption, archaeologists were aware that pyramid construction amongst the Cara appeared to begin in the late 1200s or early 1300s AD (Narr and Schönfelder 1989; Wurster 1989). Quilotoa ash also appears within numerous raised field systems throughout the region and appears to be the primary reason for the collapse of such systems (Knapp 1988; Knapp and Mothes 1998). Micromorphological analysis of sediments within these raised fields indicate ash was initially pushed to the side an attempt to clear the fields but they were ultimately filled and abandoned (Wilson et al. 2002). The significant drying noted by Ledru et al. (2013) during the post-Quilotoa period may also play a factor in the abandonment of these raised field systems. Changes in ceramic styles have also been noted in the post 1280 AD Late Integration Period (Schönfelder 1989). Though a clear association exists between the Quilotoa eruption and cultural changes in the northern highlands after, the exact relationship and mechanisms driving these changes is still poorly understood.

Cotopaxi Volcano. A lesser known volcanic eruption that is certainly significant for its historical consequences and the chronostratigraphic marker produced by its ashfall is the 1533 AD eruption of Cotopaxi volcano. A full explanation of the significance of the eruption requires a brief historical context. As mentioned previously, 1533 AD is the year that Spanish captain Benalcazar defeated the Inka general Rumiñawi at the battle of Tiocajas near Riobamba cementing the Spanish victory over the Inka in Ecuador. Juan de Velasco (1841 [1789]) writes that during the battle, though the Spanish were badly outnumbered by the Inka and Rumiñawi had prepared traps for the Spanish cavalry and arquebusiers, an unexpected occurrence saved the Spanish from defeat. While in the midst of combat, Cotopaxi volcano erupted. Rumiñawi interpreted the eruption to as a bad omen and withdrew his troops heading northwards back to Quito. As he passed, the Inka general ordered that important sites be burned rather than fall into Spanish hands. Cieza de Leon (1989 [1553]), in reference to this event refers to Cotopaxi volcano as an oracle, reinforcing the concept that the volcano held prognosticative abilities. It is for this reason that the 1533 AD Cotopaxi ashfall represents a chronostratigraphic marker for the contraction of Inka control in Ecuador and the transition into history with the initiation of the Colonial Period.

Though some have viewed Rumiñawi's decision to withdraw his troops and return to Quito as a fatal mistake for the Inka empire, the history of Cotopaxi's volcanic eruptions may shed some light on the considerations that fueled this decision. Cotopaxi volcano is located in the center of the Interandean Valley between Riobamba and Quito. Mudflows from eruptions of Cotopaxi travel north and south through the valley eventually reaching all the way to the coast. A historic account by the Spanish captains

Juan and Ulloa (1748) that accompanied the French Geodesic Expedition as well as an account by Alexander von Humboldt (1883 [1862]) suggest that the town of Latacunga, to the south of Cotopaxi, had been completely buried by these mudflows. The English mountaineer Edward Whymper (1894) used various reports of the time at which a mudflow from an 1877 eruption of Cotopaxi reached different locations, to determine that the mudflow moved at a mean rate of 20 miles (32 kilometers) an hour. The Smithsonian Institution's Volcanos of the World Database lists these various historic eruptions as being between a 2 and a 4 on the VEI. The 1533 eruption of Cotopaxi that took place during the battle is listed as a VEI of 2 indicating that similar effects were likely produced during this eruption. Thus, the 1533 eruption may have created significant impediments to the Inka army and would have made access to Quito from Riobamba difficult. A hasty retreat on the part of Rumiñawi may have been an attempt to outpace the effects of the eruption and maintain access to troops and resources in Quito. Despite his efforts, the Inka never fully recovered from the defeat at Tocajas and the last years of Inka resistance in Ecuador would be spent, not in an all-out military campaign, but fleeing the Spanish advance in opportunistic guerilla-style warfare.

Discussion

The importance for ancient people and farmers to monitor and provide due reverence to volcanos is made clear by the stories and myths presented here. The fact that particularly cataclysmic eruptions are associated with extreme changes in agricultural practices, migration patterns, and lifeways was probably not lost on the ancient people of Ecuador. The concept fits well with the Andean concept of *pachacuti* or a remaking of the world associated with earthquakes. The indigenous people of Ecuador may have had a similar

concept related to volcanic eruptions. The fact that eruptions, as in the case of Cotopaxi, heralded political upheaval lends credence to this interpretation. Archaeologist David O. Brown has suggested that the Inka temple at San Agustín de Callo, at the foot of Cotopaxi volcano, may have been built in reverence to the many volcanos that can be seen from the site (personal communication 2012). On a clear day, five of Ecuador's most grandiose volcanic peaks can be seen from its location including Cotopaxi, Las Illinizas, Sangay, Chimborazo, and Tungurahua. Appeasing Cotopaxi and predicting its activity may have been paramount to avoiding or foretelling such political upheavals. Every local group likely felt the importance of appeasing and monitoring their own regional volcanic peaks for the continuity of day-to-day life and the avoidance of catastrophe. Given the sacred nature of volcanos in ancient Ecuador, it should be no surprise that volcanic ash may have held particular significance in the cosmology and mythology of its ancient people.

VI. CERAMICS

Volcanic ash has been used for thousands of years for a variety of purposes including ceramic production. Because specific types of ash with particular chemical and physical properties would be required for particular technical purposes and would be limited to certain time periods and geographic extents, knowing what types of ash were used for what purposes and when, can provide information on time period, areas of cultural influence, and patterns of exchange. Ceramics especially have the potential to provide clues to ancient technical knowledge and patterns of exchange. Not only is volcanic ash an integral component in the formation of desirable ceramic clays, but it may have been brought great distances to be used as temper in ceramics, and its heat resistant properties were recognized and utilized by ancient people for managing temperature during the firing process. Information on volcanic ash use in ceramic production in Ecuador is sparse and the examples provided here were collected from a number of sources throughout various time periods and regions of the country wherever they could be found.

Clays and Clay Formation

Kaolinite clays are formed in older soils from heavily weathered materials in tropical and subtropical environments where heavy rain and acidic soil conditions remove most elements with the exception of silicon and aluminum (Buytaert et al. 2005; Rice 2015). Kaolinite clays are highly desirable materials today as they appear to have been in the ancient past. They are used to make thin and highly vitrified products such as porcelain, they shrink little when dried, they polish easily, and they can resist melting at low temperatures (Rice 2015).

In Ecuador, volcanic ash serves as the primary parent material for soil formation which provides unique chemical and physical properties to the resultant soils (Minc et al. 2016; Shoji et al. 1994). Volcanic ash is a glassy material with high aluminum and high silica content, which is quite soluble. During the rainy season, silica is dissolved from the ash forming allophane, imogolite, and alumina which leach to crystalline clays during the dry season in a process that may result in southern Ecuador's kaolinite clay deposits (Minc et al 2016; Zehetner et al. 2003). Around the Cuenca basin, the clay source known as C-1 is highly prized by contemporary ceramic producers as an additive to other clay materials and its use may have its roots in the ancient past. Clay source C-1 is 35% disordered kaolin, which serves as a catalyst for vitrification in the correct firing conditions, allows for the production of highly vitrified sanitary ceramics and tiles (Faieta-Boada and McColm 1993). During vitrification, crystalline particles within the clay melt and fuse sealing pores, shrinking the material, and forming a glassy final product (Rice 2015). A recent study (Jordan et al. 2014) of Ecuador's major ceramic producers and their primary clay sources found that kaolinite was the most common material amongst contemporary producers.

In the western montaña near Tulipe, Isaacson (1987) notes that a white clay, known locally as *kaolina*, is likely some form of kaolinite and is found in deposits exposed in deep creek beds in the area. This material serves as the primary source of ceramics and high-quality pigments during both the Formative and Integration Periods. Isaacson states that, during the Chorrera phase occupation, this clay was used in the creation of pedestal bowls which have very few inclusions suggesting that observed inclusions are natural. Identified inclusions in these bowls consist of rounded lithic

fragments as well as glassy pumice or lava fragments which might indicate that these kaolinite deposits, like those to the south, formed from volcanic ash.

In the northern highlands, the more consistent year-round rainfall causes the formation of amorphous minerals which result in a hardpan indurated ash layer known locally as *cangahua* in place of the B-horizon where clays typically form (Minc et al. 2016). *Cangahua* has some clay like properties but lacks the platy structure that makes clay suitable for ceramics. Clays in this region of Ecuador must form where ash has been eroded exposing bedrock (Minc et al. 2016). However, all soils formed from volcanic tephra probably have some quantity of volcanic ash (Rice 2015) and it is likely that all clays in Ecuador have some natural ash content (David Brown, personal communication 2018). Finding a desirable clay then may involve finding a source with just the right quantity of natural ash inclusions. Confirming this will require extensive petrographic and mineral studies of Ecuadorian clay sources.

Volcanic Ash as Ceramic Temper

Volcanic ash also lends its unique chemical properties to ceramics when it is added as a temper. In general, volcanic ash lowers the temperature necessary to cause vitrification thereby increasing the range of temperatures at which a ceramic piece can be fired and form a more rigid final product (Kansas Geologic Survey 2005). This can be beneficial when firing conditions limit the ability to reach high temperatures, when the materials themselves require firing be done at lower temperatures, or when the time, materials, or effort required to create a ceramic piece necessitate steps be taken to reduce the risk of failure.

The Western Montaña

John Isaacson (1987), working at the site of Nueva Era near the town of Tulipe in the western Montaña recorded a Chorrera phase occupation sealed beneath 2.5 meters of volcanic ash, which was originally attributed to a 335 BC eruption, but more likely corresponds with the ca. 450 BC eruption of Pululahua. Hollow ceramic figurines from this occupation contain inclusions within the paste which appear as reddish pellets, possibly the result of oxidized magnetite in pumice grains. Isaacson notes that these figurines are unique as the reddish inclusions are found in no other ceramics on site. Though pumice was also documented within the paste of other ceramic sherds from the site, Isaacson is unclear as to whether its inclusion was the result of unintentional or intentional processes.

Chaupicruz Phase Ceramics from Malchinguí

Meyers et al. (1981) recovered numerous vessels from two shaft tombs (designated Tomb 1 and Tomb 2) in the area around Malchinguí just north of Quito. Though the vessels were originally unable to be attributed to a particular ceramic tradition, Doyon (2002) suggests that the style of tomb along with a radiocarbon date recovered from one of the tombs dated to around 150 AD would place the tombs in the earlier part of the Chaupicruz phase (100-450 AD) just before the earliest occupation of the nearby La Florida. The Chaupicruz phase is a localized cultural phase during the Regional Development Period which is characterized by the finds at the site of La Florida in Quito.

Tomb 1 extended to a depth of 2.42 meters below the surface and had a chamber approximately one meter from floor to ceiling slightly offset from the shaft. While no identifiable human remains were recovered from within the tomb, a total of 18 vessels

ranging in color from grey to orange to yellowish brown, and consisting mostly of wide mouth jars and bowls, were found along with a pumice stone object shaped in the form of a mortar, which was suggested to be a mold for shaping ceramic vessels. The pumice stone mold was approximately 14 centimeters in diameter with a 10-centimeter diameter opening which corresponds to the bases of some of the smaller vessels found within the tomb. The large number of vessels coupled with the interpretation of the pumice stone mold led to the suggestion that this was the tomb of a potter.

Compared to Tomb 1, Tomb 2 was much deeper extending a depth of six meters below the surface with a similar offset chamber. The tomb contained only five ceramic vessels of similar colors to those found in Tomb 1 but with more elaborate geometric designs as well as a single “green stone” axe head. As with the first tomb, there were no identifiable human remains recovered. Meyers et al. note that all of the recovered vessels were created using a volcanic ash temper which contained quartz, basalt, obsidian, and mica inclusions. It’s unclear if this method of temper was used during the production of the other Chaupicruz phase ceramics recovered from La Florida, or if its use is isolated to this site.

A Comparative Example in the Maya Lowlands

For a comparative example of how volcanic ash has been used in the past and how its study may inform the archaeological record, it may be useful to look at a more studied region of the world. The addition of volcanic ash as a temper for ceramic production by the lowland Maya during the Late Classic Period (600–900 AD) has been well documented archaeologically (Ford and Glicken 1987). During the Late Classic Period, development in the highland Maya region slowed with little growth in civic centers

observed archaeologically. Meanwhile, development in the lowland Maya region increased and populations appear to have expanded. The expanded growth in the lowlands coincides with the appearance of volcanic ash temper in lowland ceramics.

Volcanic ash was used extensively in the lowland region appearing in 30-40 percent of ceramics during the Late Classic Period. The use of volcanic ash would have served to make ceramics much more stable in the traditional loosely controlled open-air pit firing regularly practiced in the region (Ford and Rose 1995). However, volcanic ash is not commonly found in the lowlands and is instead distributed in the more volcanically active region of the highlands with the closest deposits located some 300 kilometers from the lowlands (**Figure 4**).



Figure 4: The Lowland Maya region and volcanically active highlands (from Chung and Song 2014, adapted from Ford and Rose 1995).

Anabel Ford has conducted extensive research on the use and distribution of volcanic ash in the lowlands. Approximately one third of Late Classic lowland ceramics

over a three-hundred-year span were produced with volcanic ash temper, requiring an estimated 1,400m³ of ash, which Ford argues is too great a quantity to have been brought to the region by humans (Ford and Glicken 1987; Ford and Rose 1995). The uniform ash grain sizes and lack of clastics observed in these ceramics indicate that the ash was collected from a natural ashfall deposit and was not from alluvial deposits of ash naturally transported into the lowlands (Ford and Rose 1995). Zircon geochronology, which examines the rate of zircon crystallization in ash to estimate the time since it was deposited, has been used to suggest that the ash in lowland Maya ceramics from the Late Classic Period represented distal ash possibly from pre-Holocene deposits, though no such deposits have been found and this study was done using only three samples (Coffey et al. 2014). Chung and Song (2014) conducted a petrographic analysis of ceramics from Chichen Itza near the north end of the Yucatan peninsula and compared them to ceramics from several sites in the Chiapas region near the area of volcanic activity. Chung and Song apply a unique method of testing the ashfall hypothesis by assuming that if ash temper is collected from natural ashfall locally, then the particle size of the ash should reflect the natural sorting seen in ashfall. Thus, the Chichen Itza ash temper will be much more finely sorted than the Chiapas ash temper. Both samples contained ash particles of a size relative to their distance from the volcanos suggesting that the ash had been the result of natural ashfall transported by wind to the use locations.

Ford and Rose (1995) argue that regular large eruptions with a Volcanic Explosivity Index of 4 could have periodically blanketed the region with ash but concede that no associated ash deposits have been found in the lowlands to substantiate this. Instead, they propose that the volcanic ash from these eruptions was so highly desired in

the lowlands that all the natural deposits have been mined and used. The regular deposition of volcanic ash across the lowlands over long-term periods could have regularly rejuvenated the soil sustaining the agriculture necessary to support high populations in the region (Ford and Rose 1995; Shoji et al. 1994). Meanwhile, in the highlands where the effects of these volcanic eruptions were more severe, populations decreased and development slowed. It has been suggested that the ultimate collapse of the Late Classic Period Maya sites in the lowlands then may have been due to the cessation of these eruptions and the disappearance of associated ashfall leading to soil depletion and crop failure, though this claim seems dubious (Ford and Glicken 1987; Ford and Rose 1995). The example of Late Classic Period lowland Maya ceramics highlights the disconformity that may be present between ash use and ash deposits in the archaeological record; where certain types of ash are most desired, they are less likely to be found in natural deposits.

The Guangala Culture of Ecuador

The study of volcanic ash use among the lowland Maya is almost directly comparable to the case of the Guangala (300 BC to 800 AD) culture concentrated around the Santa Elena Peninsula of Ecuador. The Santa Elena Peninsula is located on the southern coast of Ecuador just north of the Gulf of Guayas and was home to the earlier Las Vegas and Valdivia cultures (**Figure 5**). The characteristic Guangala polychrome has been found from Machalilla in the north, to Punta Arenas to the south, and east as far as the Guayas Basin (Masucci 2000). Subsistence patterns at Guangala sites appear to have been maritime focused along the coast and agriculturally focused inland with a reciprocal exchange between the two regions. The Regional Development Period in Ecuador, which

coincides with Guangala is characterized by increased social complexity leading to the first recognized chiefdoms as well as increased interregional exchange. The Santa Elena peninsula has widely been recognized as a major center for the procurement and distribution of *Spondylus* and *Spondylus* shell beads (known in Quichua as *mullu*), which appears to have intensified during the Guangala occupation as evidenced by the appearance of long distance trade items such as obsidian and gold from the highlands (Paulsen 1974).

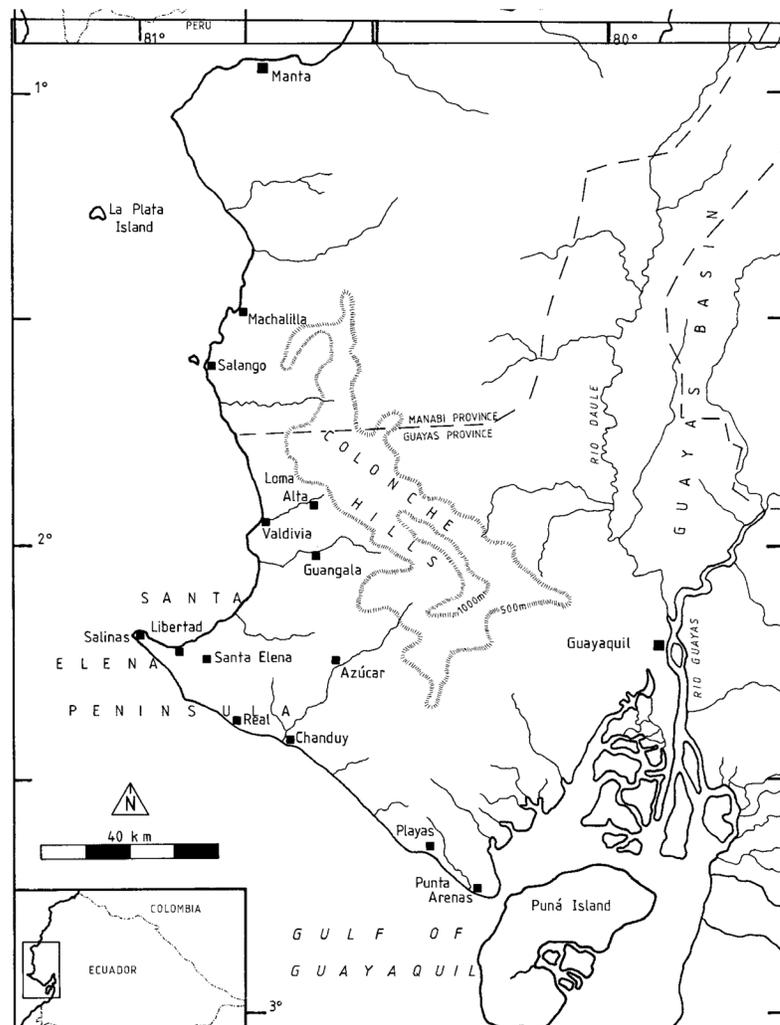


Figure 5: The south coast of Ecuador with the Santa Elena Peninsula (from Masucci and Macfarlane 1997).

Though located approximately 230 kilometers from the nearest active volcano and approximately 300 kilometers from the center of Ecuadorian volcanic activity in the north, volcanic pumice appears as one of the preferred materials for tempering Guangala fine-paste polychrome ceramics throughout the Regional Development Period (Masucci and Macfarlane 1997). The three competing hypotheses for the presence of volcanic pumice in the region suggest that it is either the result of natural ashfall, the result of the introduction of non-local clay, or the result of pumice imported from the highlands. In order to test these hypotheses, Masucci and Macfarlane (1997) conducted a petrographic analysis testing Guangala fine-paste ceramics, coarse-paste ceramics, and white on red ceramics (**Figure 6**) against local clay sources using 180 ceramic artifacts, 53 fired sediment samples, and 28 rock samples. Local clay sources were sought using local potters, local informants, and geologists. Local geology was assessed to ensure that, in the case that clay sources were missed, all ceramic samples would match expected consistency of clay formations in the region. Five sediment samples were collected from each source and four of the five were fired at temperatures between 600°–900°C leaving one unfired as a control. These sediment samples were used to create five separate local clay groups based on composition. The firing temperature was chosen to be consistent with ethnographic reports of temperatures achieved in non-kiln firing (Masucci and Macfarlane 1997).

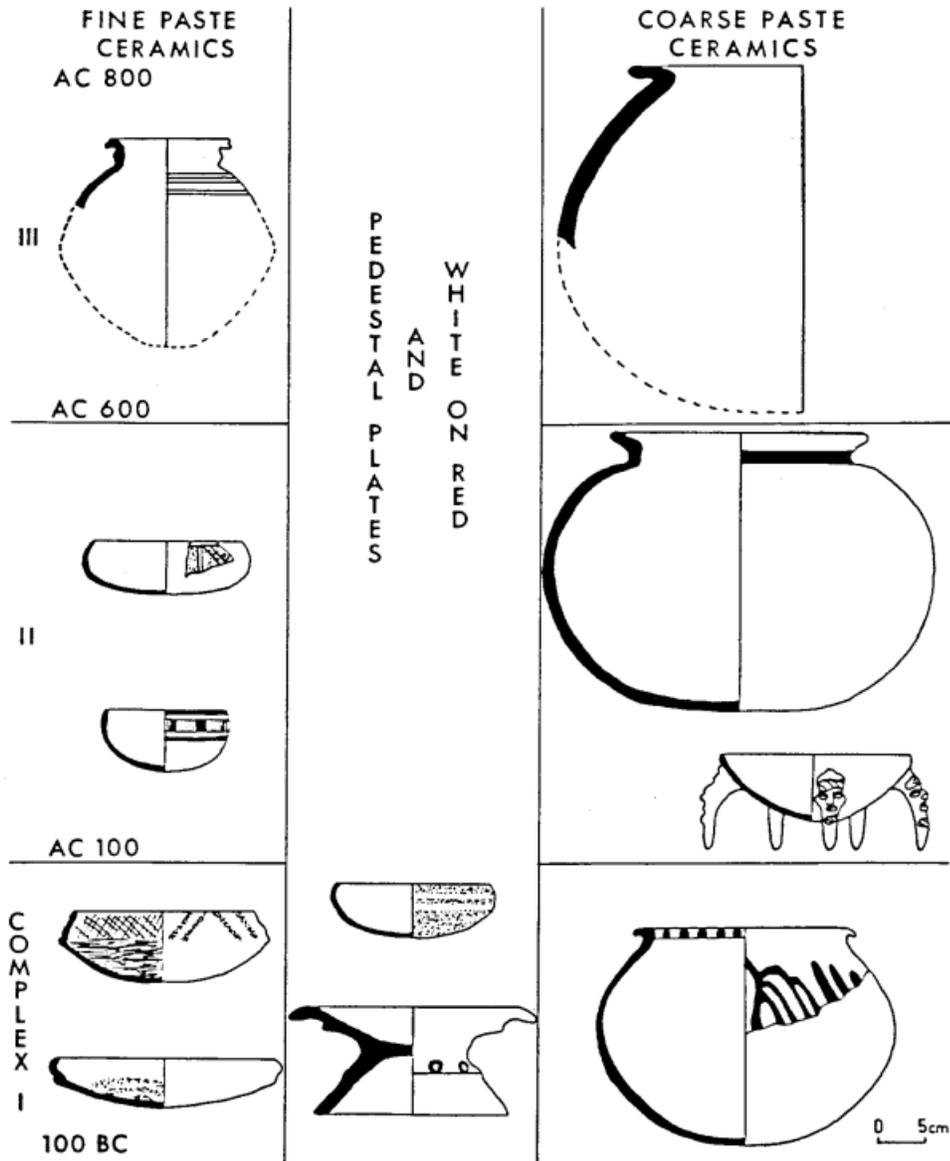


Figure 6: Guangala fine-paste, white on red, and coarse-paste ceramics (from Masucci and Macfarlane 1997).

Thin sections created from each ceramic sample were used to create six fabric classes based on internal composition. For the purpose of this thesis, Fabric Class 1 is the most notable and the only class that warrants in depth discussion as it includes all polychrome fine-paste vessels which contain pumice (**Figures 7 to 8**). Fabric Class 1 was correlated with sediment Groups I and II with the exception of pumice inclusions. Of the 53 sediment samples, no natural pumice inclusions were found within the local clay

sources. The pumice inclusions appear to be an intentional additive for tempering the ceramics (Masucci and Macfarlane 1997). The inclusion of pumice as a ceramic temper for Guangala polychrome would have decreased the risk of failure during the firing process of these already costly and labor-intensive products.

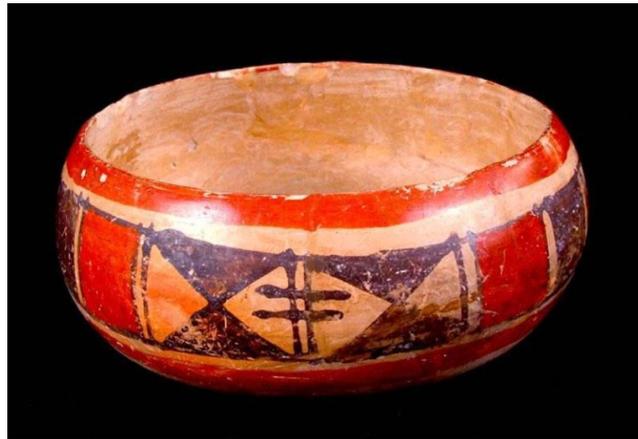


Figure 7: Guangala fine-paste polychrome (from Masucci 2008).

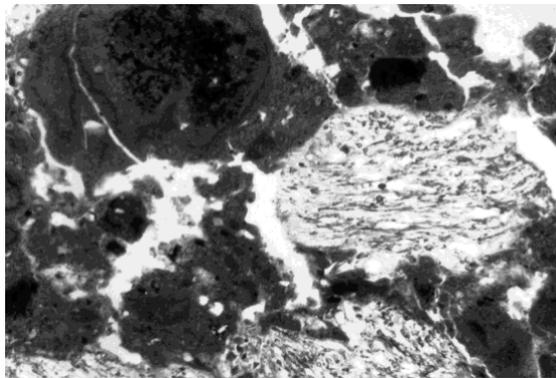


Figure 8: Class 1 pumice inclusion (from Masucci and Macfarlane 1997).

The closest coastal pumice deposits to the Santa Elena Peninsula appear in Manabí and Esmeraldas provinces on the northern Ecuadorian coast (Masucci and Macfarlane 1997). However, based on the petrographic analysis, the Fabric Class 1 source appears to be located along the southern coast. Furthermore, these north coast pumice deposits appear to contain a mix of ash and sediments indicative of float material

in drainages but not present in the Guangala paste pumice. Today, pumice is imported to the southern coast of Ecuador from the highlands in the area around the town of Ambato for use in polishing metal, skincare, and construction (Masucci and Macfarlane 1997). The lack of local pumice deposits, the existing archaeological evidence of long distance exchange with the highlands, and the contemporary use of imported highland pumice led Masucci and Macfarlane (1997) to suggest that pumice was imported from the highlands to the coast along the same exchange routes that brought obsidian. The vast majority of known obsidian sources in Ecuador are located around the Quito Basin. Additional uses of pumice among the Guangala, perhaps in construction or in *Spondylus* shell bead production, would have made long distance procurement more tenable. Pumice stone has been suggested as a tool for polishing *Spondylus* shell bead bracelets in the Aegean Sea (Gaydarska et al. 2004) and may have served a similar function amongst the Guangala.

After the Guangala occupation ends and the succeeding Manteño culture begins, volcanic pumice no longer appears as a constituent component of local ceramic paste. *Spondylus* bead production continues among the Manteño, though the ware patterns on *Spondylus* beads change indicating some shift in the production process and the focus of exchange shifts southward towards southern Ecuador and Peru. The end of Guangala culture coincides with a decrease in the presence of obsidian and precious metals at coastal sites (Paulsen 1974). This has led to the suggestion that the end of Guangala is associated with some sociopolitical change that alters the patterns of exchange between the highlands and the coast. Considering that pumice may serve multiple purposes and could travel on already established networks of exchange, it seems more probable that intentional transport is a likely explanation for its presence on the coast. However, with

the comparison of Late Classic lowland Maya ceramics in mind, it is equally possible though perhaps somewhat unlikely, that over the millennium of ash use along the southern coast, ancient ash deposits have been completely consumed.

Yet the assessment that volcanic ash use on the coast is indicative of long-distance exchange is further supported by the use of *Spondylus* in the highlands, which decreases significantly around the same time as Guangala culture's decline at the end of the Regional Development Period. Historic accounts during the arrival of the Spanish indicate that the Integration Period (800–1550 AD) site of Cochasquí in the northern highlands, a massive center with fifteen earthen pyramids and over thirty hemispherical mounds, was purchased from the local cacique by the Spanish for a quantity of *mullu* (Yolanda Navas de Pozo, personal communication 2015). This might indicate that the lack of *Spondylus* in highland contexts during later periods was due to economic realities of exchange rather than a lack of cultural interest, since *mullu* still retained enough value to the cacique to purchase such a monumental site. Potentially, the same systems of exchange bringing *Spondylus* to the highlands are bringing obsidian, precious metals, and possibly pumice to the coast and the end of the use of pumice for ceramic temper is related to the disappearance of *Spondylus* in the highlands. In this context of interregional exchange, Masucci's examination of pumice temper in Guangala fine-paste ceramics may yield clues to sociopolitical and economic conditions in the northern highlands, especially if further studies can zero in on a potential source location.

Highland Formative Period Ceramic Firing Pits

Volcanic ash may have also been used in the ceramic firing process in the northern highlands during the Late Formative Period (800 B.C.–300 B.C.). Los Soles is a

Formative Period site located just northwest of the town of Ibarra. During excavations at Los Soles, Dyrdaahl et al. (2017) documented a large ovular pit approximately 1.6-meters in diameter and 30 centimeters deep excavated into the surrounding *cangahua* (**Figure 9**). A layer of volcanic ash approximately 5-10 centimeters thick with a grain size of 0.125 millimeters, consistent with the grain size of ash from the nearby Cuicocha volcano, was found lining the walls of the pit. Pumice fragments within this ash lining were smaller than those seen in Cuicocha ash, but constant heating and cooling from the firing process may have broken them down to smaller size (Dyrdaahl et al. 2017). Below the ash layer, was an orange oxidized layer approximately three millimeters thick overlying a carbon layer composed of burned branches ranging from one to two centimeters thick. The pit itself contained slag, few artifacts, and no faunal remains. Dyrdaahl et al. (2017) noted that the pit appears to have a different composition than other known oven or cooking features from Formative period sites in the Ecuadorian highlands. So-called party-pits have been found with fill that appeared to represent evidence of ritualized feasting activity. Stoves and storage pits are typically rectangular with associated post holes and are found to be around twice as deep and with more narrow openings only half the diameter of the pit at Los Soles. Additionally, similar open-air firing pits from Oaxaca and the Moche region of Peru are described as being filled with ash, coal, ceramic residue, and slag material. The circular shape, the lack of faunal remains or artifacts, the presence of the ash lining, and the similarity to Oaxaca and Moche firing pits led to the suggestion that the Los Soles pit represents a ceramic firing kiln (Dyrdaahl et al. 2017).

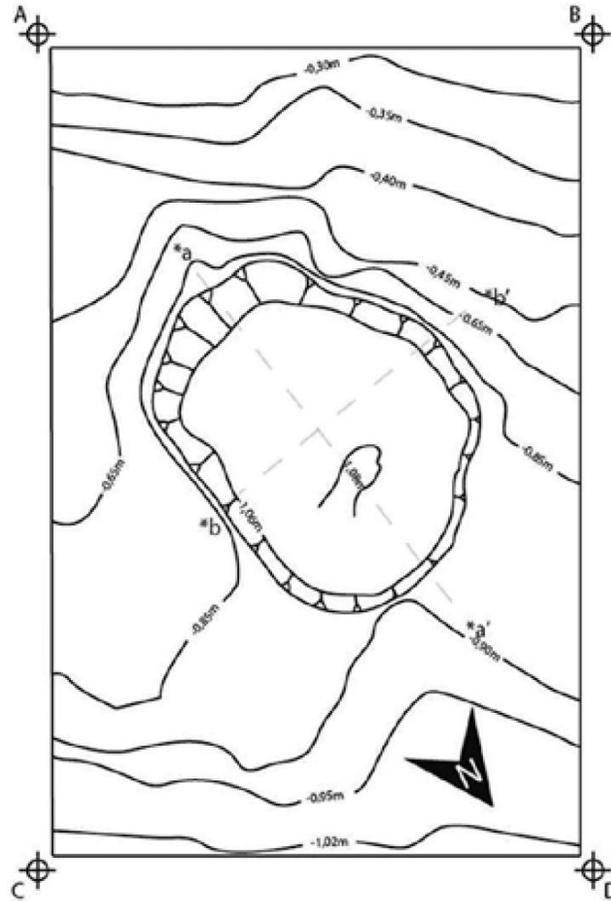


Figure 9: Plan map of open-air firing pit lined with Cuicocha ash (from Dyrdaahl et al. 2017).

The ash lining inside of the Los Soles kiln potentially served as a thermal insulating layer during the firing process. As mentioned previously in reference to lowland Maya volcanic ash temper, ash has particular heat resistant properties that make it ideal in instances when temperature control may be difficult such as with open-air pit firing. Additionally, it is likely that the same properties of *cangahua* that make it less than ideal for ceramic material also make it susceptible to constant heating and cooling events. In this sense, the ash lining of the kiln may have served to control the internal temperature while preventing the collapse of the surrounding *cangahua* matrix due to repeated high heat exposure and subsequent cooling from kiln use. In Japan, a highly volcanic country, a company called Shirasu Products Development is researching

applications for insulation coatings made from Shirasu volcanic ash, a product of Mt. Sakurajima. Shirasu Products Development has created an insulation coating of fine volcanic ash noting that the internal air inside the fine ash particles lowers thermal transmissivity (European Coatings 1999). It's possible that the ash lining of the Los Soles kiln was meant to take advantage of a similar process.

Results and Discussion

It is clear that volcanic ash has a wide variety of ancient uses in ceramics and ceramic production and its application can inform our archaeological interpretations.

Unfortunately, Ecuador is relatively poorly studied compared to other regions of the Americas and finding extensive research into the use of volcanic ash is difficult. When ash is mentioned in archaeological contexts, it is mentioned mostly in passing in relation to tephrochronology and it is sometimes difficult to determine if ash inclusions in ceramic paste is intentional or unintentional. But the potential applications of the study of volcanic ash to our archaeological practice are myriad.

Future studies could focus on the role natural ash content plays in the selection of desirable clay sources. Chemical testing of pumice inclusions in Guangala ceramics could help yield clues to its source eruption. An examination of pumice grain size in ceramics from Guangala sites on an east to west axis much like Chung and Song's (2014) study in the Maya region could lend additional support to Masucci and Macfarlane's (2000) pumice trade hypothesis. This same examination could help determine how far from the source volcano the material was collected by determining if it represents proximal or distal ash deposits thereby yielding clues to its original location. Cryptotephra techniques could be employed to find heavily eroded ancient ash layers that long ago became

invisible to the naked eye in order to determine if there once were ancient ash layers in the Santa Elena Peninsula. Experimental studies of ash-lined open-air firing pits could help determine what insulation benefits ash lining renders, what sort of preparations are necessary to form such a lining, and how many times an ash lined a kiln can be used before there is a marked chemical or physical change in its composition. Finally, many more ethnographic studies need to be undertaken to understand how volcanic ash today is mined, processed, transported, and used for ceramic production as a temper but also for any other role it may serve in the production process. Only once we have a complete understanding of the range of benefits of volcanic ash can we begin to recognize the way it has been perceived, utilized, commodified, exchanged, and exploited.

VII. RITUAL AND BURIAL PRACTICES

Given the imposing nature of volcanos on the landscape, the dramatic effect their eruptions can have on nearby populations, and their status in local mythology, it is unsurprising that volcanic ash appears to have held a significant place in prehistoric Ecuadorian ritual and burial practices. There are numerous instances of volcanic ash being intentionally incorporated into burials throughout the northern highlands among a variety of cultures. Because volcanic ash is one of the products of volcanos most closely associated with eruptions, examining the different uses of volcanic ash in ritual and burial contexts can serve as an indicator of ancient beliefs, religious practices, as well as conceptions of volcanic eruptions and volcanos on the landscape.

The cultures throughout the Ecuadorian highlands during the Regional Development period practiced various forms of shaft tomb burials (**Figure 10**). Evidence of shaft tomb burial traditions extend from the Cañari culture in the south around the Cuenca basin to the cultures of the Upper Cauca and Upper Magdalena river valleys in southern Colombia (Doyon 2002). Within these traditions, the depth of the tombs apparently related to the social status of the individual or individuals interred. The deeper shaft tombs often exhibit more elaborate grave goods than their shallower counterparts. The enclosed nature of these tombs indicates that only a few workers would be able to excavate a single tomb at a given time. This is in contrast to the later burial mounds and pyramids of the Integration Period, which would have required a great deal more people and were likely conducted under the direction of a few individuals.

While early excavations of shaft tombs focused almost exclusively on the shape of the tomb and the grave goods within, archaeologists have recently begun to consider

the sediments used to fill these tombs (Doyon 2002). More recent excavations indicate that sediments removed from the tomb were not always used to fill the tomb (Doyon 2002; Wentscher 1989). Instead, the tombs may have been filled with an intentional sequence of layered sediments, which may have held some symbolic meaning for the builders. Volcanic ash sometimes appears prominently within these sequences.

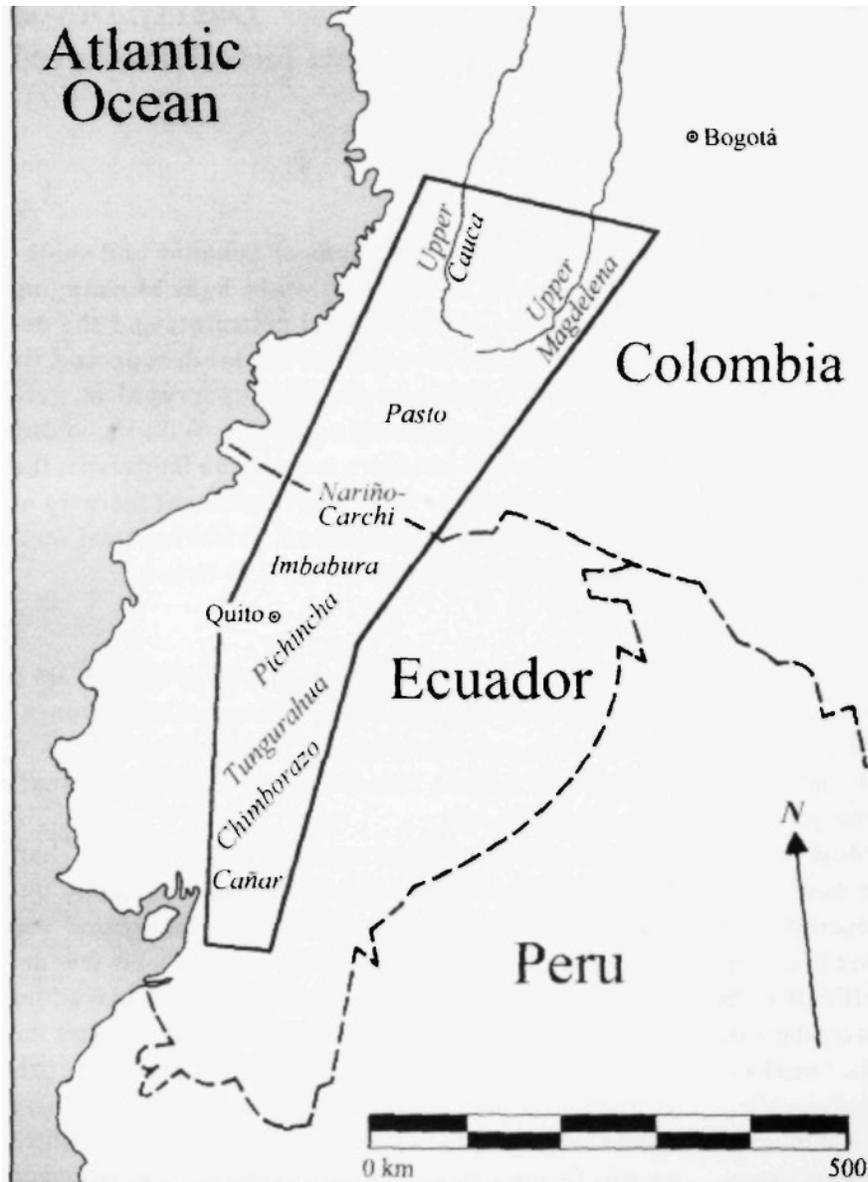


Figure 10: The extent of highland Ecuadorian and Colombian shaft tomb traditions (from Doyon 2002).

During the Early Integration Period of the northern highlands (800-1280 AD), the practice of shaft tomb burials was largely discontinued in favor of burials interred within hemispherical earthen mounds, though that shaft tomb construction may have continued for some time farther north. The appearance of extremely shallow shafts for the burial at the base of the mound, along with the layering of sediments above the shaft to create the appearance of an artificial shaft tomb within the mound, may hint at some cultural connection between the earlier shaft tomb and the later burial mound traditions. . It has even been suggested that the various depths and forms of the tombs during these periods culturally and temporally diagnostic (Doyon 2002; Porras 1980) (**Figure 11**). However, Brown (2018) has argued that there is little evidence in monumental architecture or ceramic typology to suggest a connection between the shaft tomb building people and the hemispherical burial mound building people. Camino and Sánchez (2018) point out that while well-developed ceramic typologies exist for the Integration Period, such typologies have not been developed for the Regional Development Period with which we can reliably attribute tombs to cultural phases.

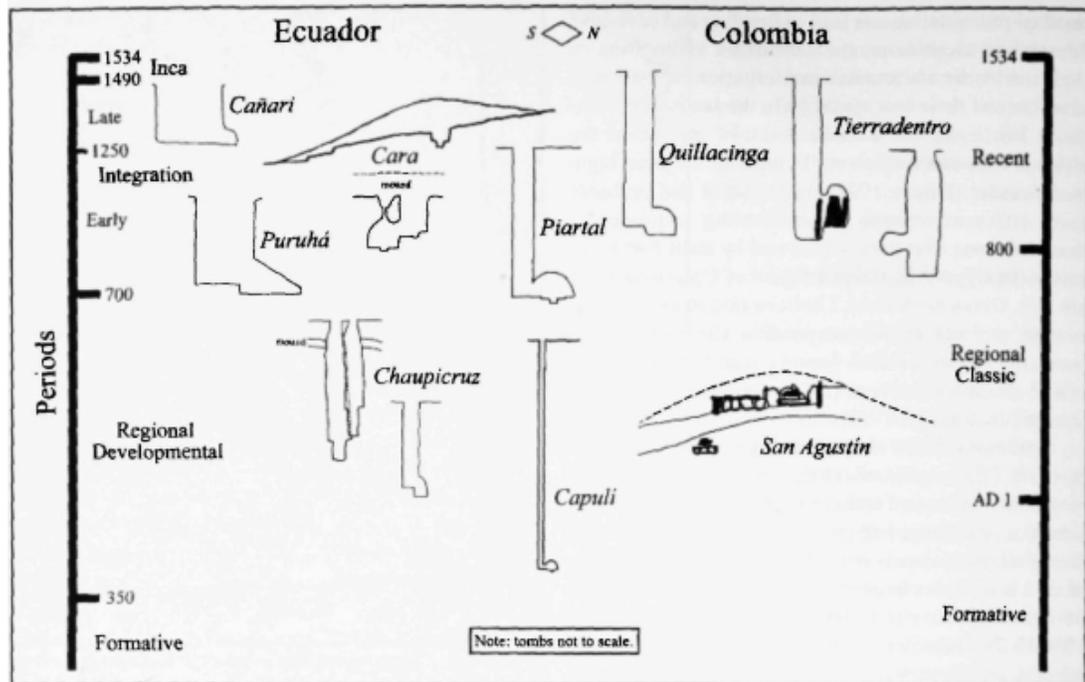


Figure 11: Various highland Ecuadorian and Colombian shaft tombs (from Doyon 2002).

Many of the examinations of burial practices in the Regional Development and Integration Periods of the highlands fail to address the complexities of ancient burial practices. As Leon Doyon (2002) points out in his syntheses of burial traditions in the Ecuadorian and Colombian highlands, some of the human remains recovered from La Florida bear evidence suggesting secondary internments and stratigraphic evidence indicates some tombs were left open for some time and may have been periodically reentered. Doyon suggests that individuals from these sites potentially underwent some process of mummification and were left on display before being interred or that ancestors may have been removed from their original tombs to be reinterred in more elaborate group burials with their kin Doyon suggests that reentering and removing the deceased may also be indicative of an effort to delegitimize political rivals through the destruction of their ancestors. The idea of reinternment and removal would certainly explain some of the confounding inconsistencies with tombs during these periods, which are sometimes

found to contain no human remains. As Doyon points out, Ecuadorian archaeologist Jijón y Caamaño (1920) documented secondary internments still being practiced in Pichincha province in the early twentieth century. Relatives of the deceased would remove the remains of the originally interred individual and replace them with the recently deceased individual though it's difficult to say how whether this practice is indigenous or a Colonial introduction. Portions of the remains of the original individual were returned to the tomb to rest alongside the newly interred. Such complex burial practices force us to reconsider the nature of the taphonomic and stratigraphic evidence observed within these tombs. Unfortunately, in the 100 years that shaft tombs and burial mounds have been excavated, archaeologists have only recently begun to take note of the sediments which compose them.

Volcanic Ash and the Shaft Tomb Traditions

The earliest of the shaft tombs in Ecuador were extremely deep dome-shaped chambers from the Capulí phase (300 BC-300 AD) in the Nariño-Carchi region along the Colombian border (Doyon 2002). Elite individuals from this phase were interred in tombs ranging between 9 and 40 meters below the surface. This cultural tradition is recognized almost exclusively by their burial practices and little is known about the living people that oversaw the internments. Many of the tombs from the Nariño-Carchi region were apparently excavated to the depth of or just below natural ash layers (Doyon 2002). In this sense, the ultimate depth of the tomb may have been dependent on the depth of particular underlying ash deposits. In some instances, once the tombs were ready to be closed, sediments from middens were used as fill in place of those removed (Doyon 2002).

At the Chaupicruz phase (100-450 AD) site of La Florida in Quito, Doyon (1988; 1998; 2002) excavated six shaft tombs in an apparent mortuary complex overlooking an ancient lake which was drained by the Spanish in the early Colonial era. Some of the individuals recovered were bundled and missing their lower extremities with evidence of postmortem modification. Five of these six tombs extended to a depth of 14.2 to 15.1 meters, at or just below the depth of three natural ash layers which were prominently mixed within the subsequent fill. The sixth tomb extended a depth of 12.5 meters and may have reached these ash layers as well but was heavily impacted by looting prior to excavation. Nonetheless, volcanic ash appears as a significant component in the disturbed fill of this tomb as well. Individuals within these tombs were found in elaborate *Spondylus* shell ponchos with metals, textiles, numerous ceramic vessels, and two emerald beads found with two of the individuals which led to the conclusion that these were elite individuals (Doyon 1988; Ubelaker 2000). Remains of human crania near the surface of these tombs were interpreted to be the remains of sacrificial victims made as offerings to the deceased sometime after the closing of the tombs. Other shallow dome- and bottle-shaped shaft tomb burials around the periphery of the site were intentionally filled with a pure white volcanic ash (Doyon 2002).

Shaft tombs from the Cosanga-Pillaro III & IV phases (ca. 700-1490) during the Integration Period are relatively shallow tombs ranging from 1.5 to two meters in depth with small lateral offshoot chambers lined with cane (Porrás 1980). Remains within these tombs are often disarticulated suggesting a secondary internment and sometimes exhibit evidence of burning as though hastily cremated. These tombs are always constructed with

a layer of volcanic ash, known locally as *pugshi*, spread across the floor before internment (Porras 1980).

Volcanic Ash and Hemispherical Burial Mounds

The tradition of including volcanic ash in funerary contexts continued from the Regional Development Period into the Integration Period with the transition to hemispherical mounds. Cochasquí (ca. 950-1550 AD) is an Integration Period Cara monumental site located on the slopes of Mojanda north of Quito overlooking the Interandean Valley. The site, which originally boasted an impressive 15 truncated pyramids and over 30 hemispherical earthen mounds, was excavated extensively in the 1960s by archaeologist Udo Oberem and his team who dubbed themselves grupo del trabajo Ecuador.

Radiocarbon dates collected during these excavations attributed construction of the mounds and pyramids to two different phases of occupation with the Cochasquí I phase (ca. 950-1250) associated with the construction of the earthen burial mounds and the Cochasquí II phase (ca. 1250-1550) associated with the use of the truncated pyramids.

During their excavations, Oberem and his crew created a lettering system that distinguishes between truncated pyramids and hemispherical burial mounds. In this lettering system, pyramids were assigned capital letters A through O and the hemispherical mounds that they were able to recognize at the time were assigned lower case letters a through x. Oberem excavated portions of several of the pyramids (E, G, H, J, K, L, O, and M) as well as four of the hemispherical mounds (a, h, n, and x) including the entirety of Mound n. Of these four hemispherical mounds only three (Mounds a, h, and n) appeared to be classic burial mounds containing shallow tombs. Two of these three, Mound h and Mound n, bear evidence of reentry in their stratigraphic profiles and

contained no human remains (Wentscher 1989). Mound h appears to have been reentered from above while Mound n appears to have been reentered from the side. In both cases, vessels were left in the tombs and the tombs were reconstructed. Mound x, the largest hemispherical mound on site, appears to be a more complicated structure. Interestingly, both Mound n and Mound x appear to have been constructed atop arroyos, the one beneath Mound n apparently being active for some time after construction (Wentscher 1989). There may have been an intentional effort on the part of the builders to associate these structures with these natural features.

While Mound x itself contains no burials, it does overlies eight bottle-shaped pits that Wentscher (1989) identified as cremation pits. It also exhibits evidence of occupational surfaces where dense layers of carbon, faunal remains, and organic material as well as rectilinear cooking features suggest ritual feasting took place. It is also notable that Mound x was recorded as having the local name *Ushpa-tola* or “Ash-tola” by the grupo del trabajo Ecuador (Wentscher 1989). While much of the ash from which it likely draws its name is the product of intense burning potentially associated with periods of ritual feasting, there are thin layers of Pululahua 450 or 690 BC ash incorporated into portions of its construction which I documented during a 2018 reexamination of the open excavations at Mound x. These ash layers are not immediately indicative of some organized construction pattern. Though its appearance within the mound stratigraphy doesn’t necessarily suggest intentional inclusion, the ash is much finer grained than the natural lenses of Pululahua found around Cochasquí suggesting that it may have been processed or sorted in some way before its inclusion. The name of the mound may also come from the thick layer of fine white ash from an unknown eruption that covers the

mound sealing the underlying cultural deposits. The radiocarbon dates recovered from within the mound date its occupation to between 1260 and 1300 AD (Narr and Schönfelder 1989) which might indicate that this fine white ash is the result of the 1280 AD Quilotoa eruption. However, a visual inspection of the ash suggests it may lack the quantity of biotite inclusions that are diagnostic of the 1280 AD Quilotoa ashfall. This ash then may be the product of some yet poorly documented eruption which occurred around the same time, perhaps the 1290 AD eruption of the nearby Cayambe volcano.

The hemispherical burial mounds at Cochasquí were constructed above shallow tombs excavated into the natural ground surface. Soil from these pits was tossed to the side rather than returned to fill the tomb. This pattern is visible within the profile of Mound a (**Figure 12**). In its place, layers of clay, sand, and volcanic ash were intentionally deposited within the tomb. Oberem describes the process of mound construction thusly:

First the tomb was excavated, then, around it, a part of the mound was selected [built?]. Finally, after carrying out the funeral itself, the tomb was filled and closed with thin layers of mud. At the closure of the tomb, a layer of white powder of pumice stone was placed, which stands out very clearly. Furthermore, this stratum of pumice stone is also found in other funerary mounds with a tomb in the Cochasquí region. At this time, the mound was again piled up and finally the remaining middle part was filled over the tomb and then everything was covered with the upper layer... (Oberem 1981 [translation by author]).

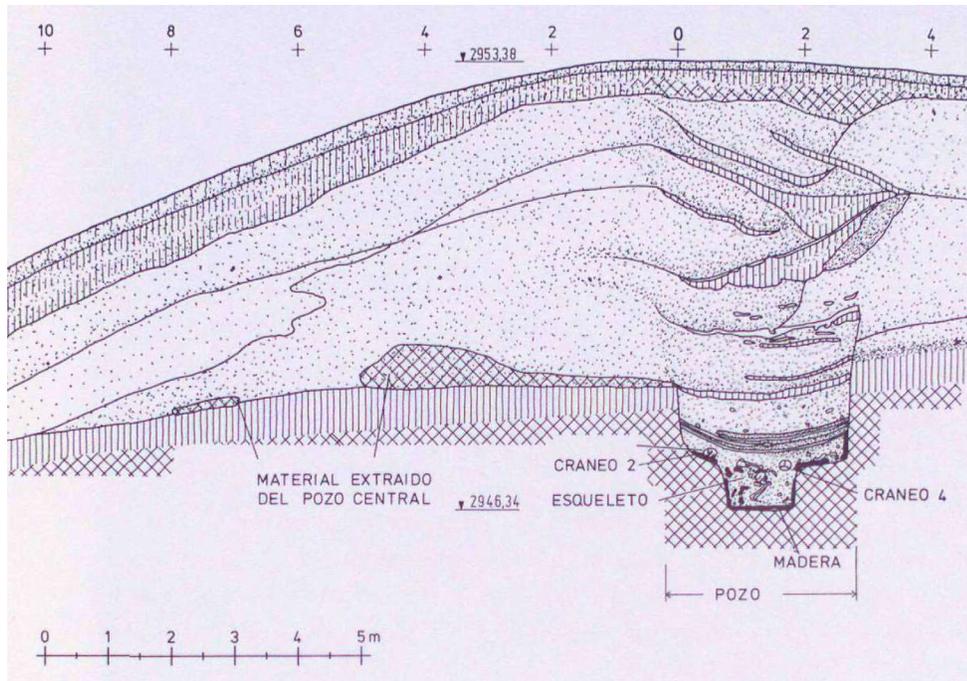


Figure 12: Profile drawing of Mound a showing intentional layering of tomb sediments and the discard of the original sediments. The volcanic ash is represented by the single white stratum near the middle of the shaft (from Wentscher 1989).

It's notable that, given the description of the sequence of mound construction provided by Oberem, after the sealing of the tomb with volcanic ash and prior to the filling of the upper portion of the shaft, the mound would appear to contain a crater much like the crater of many of the volcanos in the region. At this intermittent stage, the volcanic ash layer would have appeared from above as a bright white disk at the bottom of the artificial crater. Such a structure would not be without precedent. Benfer and Ocás (2017) documented a pyramid in the Nepeña Valley of Peru that was built with a crater in order to imitate a nearby cinder cone volcano. Why construction of the mounds of Cochasquí was carried out in this sequence of successive phases rather than just completely topping off the mound in a single phase is unclear but was likely related to some ritual activity performed during this stage before finally sealing the burial shaft. Also of note for the purpose of this thesis was the discovery of six cone-shaped pumice

stone objects, one from within Mound n, one from within Mound x, and four from a nearby area referred to as the location of a possible pueblo. These conical objects have flattened or convex bases which are either polygonal or circular. Zalles-Flossbach (1989) who conducted the lithic analysis of the materials collected by grupo del trabajo Ecuador suggested that these cones were soft anvils on which metals could be hammered and shaped [hard to imagine any pumice being hard enough to hammer metals on].

It is quite probable that the layering of sediments within the mounds represents an intentional organization on the part of the builders, likely with some symbolic significance. As stated by Oberem (1981), this layer of white ash stands out clearly amongst the other layered strata that fill the shaft of the tomb (**Figure 13**). The stark contrast between the layer of white ash and the other sediments chosen might suggest it held a unique place in the symbolism of builders. Interestingly, though Mound h appears to have been reentered, its occupant removed, and much of the intentional layering of sediments disturbed, the layer of volcanic ash was returned before the mound was reclosed. This would indicate that the evidence of reentry was not the result of looting and that the layer of volcanic ash is such an integral part of the construction of the mound, that it had to be laid back in place before resealing the empty tomb.



Figure 13: Layered sediments from the tomb shaft within Mound a (from Oberem and Wurster 1989).

Volcanic Ash and Pyramid Burials

As with the shaft tomb and burial mound traditions, volcanic ash also appears to have been a component in burials within the larger truncated pyramids of the Late Integration Period. Though the function of earthen monuments appears to shift from mortuary structures to areas of communal ritual activity, burials are occasionally found within these pyramids. The town of San Rafael is situated on the southern banks of Lago San Pablo near the current town of Otavalo. On a prominent ridge line on the slopes south of San Rafael are three large truncated pyramids and a number of smaller mounds and pyramids which may mark the original location of ancient Sarance. Within San Rafael are

a number of truncated earthen pyramids that have been impacted by the constant urban development there.

During a trip in August of 2017 to the pyramids of San Rafael, I encountered a pyramid bisected by the construction of an adjacent *cancha de futbol*. The pyramid was composed of three major construction sequences. What appeared to be a shaft tomb was visible extending from beneath the final phase of construction near the surface of the pyramid reaching to the base of the pyramid. This shaft was approximately 3.5 meters deep and 3 meters wide. The final layer of the pyramid which was laid over the shaft contained intact cultural material including half of a ceramic vessel that had been cut during construction of the *cancha de futbol* and was clearly visible within the profile. The shaft, which notably terminates just below the level of a natural pumice layer, contains large blocks of fine white ash material from an unknown eruption (**Figure 14**).

Future excavations would be required to confirm whether this shaft indeed represents an intact burial with intentional volcanic ash intermixed. However, the presence of this deep shaft which intrudes upon the natural pumice layer and is sealed by the final layer of the pyramid is a clear indication that it is an intentional feature of the pyramid and not the result of looting. Since earthen pyramids, succeeding hemispherical earthen mounds and shaft tomb traditions, are considered to be relatively late in Ecuadorian prehistory, this ash filled shaft tomb might represent a continuity between the earlier shaft tomb and burial mound traditions, which incorporated volcanic ash, and the later truncated pyramid tradition.

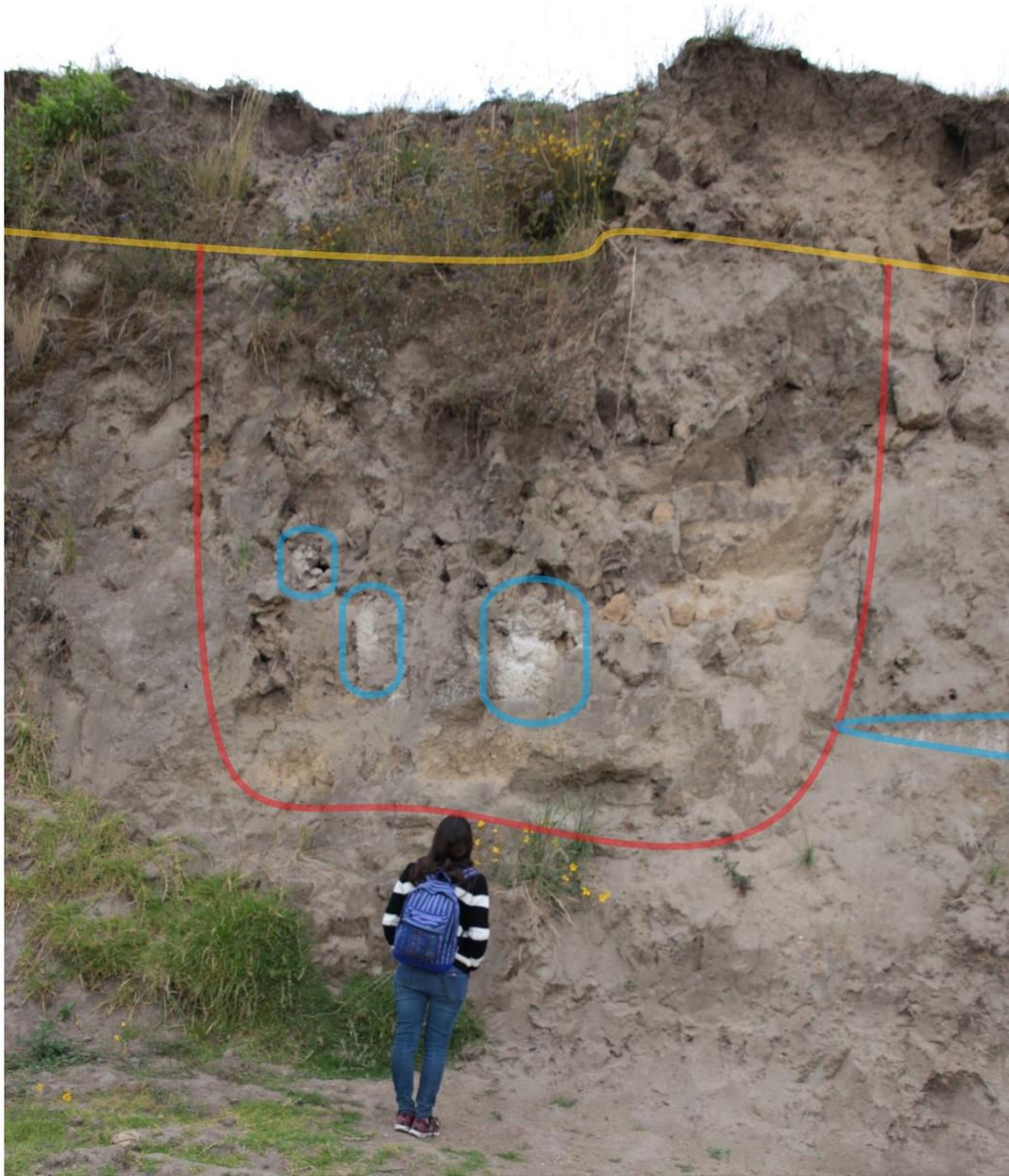


Figure 14: An apparent shaft tomb (marked with red) within the pyramid at San Rafael. Volcanic ash is outlined in blue and the lower boundary of the final phase of construction is marked by yellow (photo by David O. Brown).

An Anomalous Instance of Volcanic Ash Incorporated in a Burial

An instance of a somewhat anomalous burial from the highlands near Cochasquí underscores some of the difficulties and inconsistencies with recognizing the intentional addition of volcanic ash within burials. Rather than representing an extensive burial

tradition, the below instance may represent an isolated case within the broader cultural context that may be a cryptic hint towards individual identity or status which should be further explored. As mentioned previously, little attention has been given in the past to individual sediments within burials or volcanic ash in association with burials except regarding volcanic impacts or tephrochronology. This isolated case highlights the importance of detailed sediment analysis during the excavation of burials in the future in order to distinguish unique burial traditions which may extend beyond broad cultural groupings or the analysis of grave goods and lead to more complex inter and intra site comparisons.

At Cochasquí, a single exhumed burial now resides within the onsite museum of the archaeological park (**Figure 15**). This burial was not found within the existing confines of the park during the archaeological investigations there, but rather was recovered during a salvage project along the upper slopes north east of the park during construction of a canal system between Tabacundo and Malchinguí. The tombs were found uphill from the site of Huaraquí (Guaraqú), an Early Integration Period site with several hemispherical earthen mounds which was excavated in the early 1950s (Guignabaudet 1953). The early reports of the site do not indicate the exact number of mounds present, but recent satellite imagery suggest a concentration of approximately five mounds in the area. Due to the early date of the excavations at Huaraquí, there are no radiocarbon dates, but the descriptions of the mounds and the “oven” features discovered there suggests that it was likely contemporaneous with the Cochasquí I phase occupation (ca. 950-1250 AD) where similar features are documented.



Figure 15: Burial recovered from the slopes above Huaraquí (photo by author).

The report on the salvage excavations near Huaraquí (Gobierno de la Provincia de Pichincha 2001) provides few details on the four tombs that were found and excavated. No drawings of the tombs or the layout of the excavations are provided within the report, but the descriptions indicate that they were shallow lateral shafts extending between 0.6 and 0.9 meters below the surface. There are only basic sediment descriptions, a single Munsell color provided for each feature, and no mention of volcanic ash, so it's unclear which of the four burials excavated during the course of the project this individual came from. Nonetheless, Fritz Reinhaller, the Cochasquí park director who was present during the excavations, informed me that the layer of volcanic ash that the remains are currently displayed on in the museum is the original ash from the base of the tomb in which the individual was found (personal communication 2018).

There were no grave goods associated with the burial, those within the case at the museum were placed simply for the purpose of display. Other tombs found during these salvage excavations contained much more elaborate grave goods; one notable example contained 11 ceramic vessels. Yet despite the number of associated grave goods, the shallow nature of the tombs and their relation to the Early Integration Period site of Huaraquí suggests that these individuals may be those of too low status to warrant the burial mounds afforded to much higher-status individuals during this time period. The shallow extent of the tombs also conforms with the depth of tombs not associated with burial mounds found around Cochasuquí (Wentscher 1989). Alternatively, given the location of the tombs within an agricultural field and the poor sedimentary description of the site, it is possible that the remnants of such a mound went unnoticed. In either case, significant questions remain. Why was a single individual interred with no grave goods but a collection of volcanic ash? Was the ash considered to be an acceptable substitute to a family which had little in the way of material goods to offer? Was it the sign of a healer, a shaman, or a disgraced individual? Was the tomb reentered and vessels removed? Careful assessments of sedimentary evidence within burials in the future could seek to answer some of these questions.

Results and Discussion

Given its prolific association with highland burial practices during the Regional Development and Integration Periods, there can be little doubt that volcanic ash held a significant place in the cosmology and mythology of the ancient people in this region. Understanding exactly how the variety of unique burial practices involving volcanic ash fit into the broader cosmological framework will take detailed sediment descriptions,

analysis of grave goods, and inter as well as intra site comparisons. In any case, it's clear that volcanic ash is associated with death and the dead, a connection that is undoubtedly rooted in the acknowledgement of the destruction that relatively light ashfalls can wreak on the landscape and its inhabitants.

In the Regional Development Period shaft tombs, the white ash fill found within some tombs is contrasted by the dark midden fill used in others. The significance of this dark-light juxtaposition is unclear, but it represents a pattern that continues into the pyramid construction of the Late Integration Period which will be discussed in more detail in Chapter VII. It may reflect concepts of duality associated with gender, identity, or status which aren't readily apparent. A detailed comparison between individuals and grave goods found within these tombs could seek to address some of these issues.

Chemical and visual analyses of volcanic ash within funerary contexts could help to determine if volcanic ash from a particular eruption was preferred for these practices or if any available ash would suffice. Preference for a particular volcanic ash from an eruption in close temporal proximity to the occupation might suggest some cultural or historical memory of the eruption and intentional inclusion as a symbolic reference to the actual event.

Examinations which view burials as static time capsules fail to address the complexities of the ever-changing relationship between the living and the dead that may represent day-to-day interactions as well as moments of political or social upheaval and regime change. Reentry events may be visible through the disturbance of strata which were intentionally placed in the tomb by its excavators. Doyon (2002) noted that microstratigraphic evidence of wash events could be seen within some of the shaft tombs

indicating that the tombs had been left open during episodic rains. Since rain would have been extremely hazardous for the excavators, it's likely that construction of the shaft tombs only took place during the dry season. Wentscher (1989) also noted micromorphological evidence of wash within a disturbed portion of Mound n at Cochasquí indicating that a section of the mound had been reopened and exposed to rain at some point during its use. In any case, the use-life of these monuments appears to have come to an end after the 1280 AD eruption of Quilotoa, evidence of which can be seen just southwest of Cochasquí at the site of El Campanario where a looted burial mound is sealed by the layer of Quilotoa ash. Detailed geoarchaeological investigations of the use life of tombs could treat mortuary contexts as dynamic features in the broader cultural landscape and reveal minute differences in funerary practices through variations in individual internment episodes within a single context, variations which may represent changing ideologies. Only through careful reconstructions of the episodic life histories of these monuments to the deceased can we hope to reveal the complex tapestry of interactions between the living, their ancestors, and the afterlife. Volcanic ash, with its widespread use in burial practices, its ability to be easily recognized and sourced, the myriad of ways it appears in these contexts, and its connection to both the sacred and physical landscape can serve as a key component in these interpretations.

VIII. CONSTRUCTION

Construction represents the largest category of volcanic ash use discussed in this thesis. Many of the examples presented in this chapter come from discoveries during my own work or related research in the northern Ecuadorian highlands in Cotopaxi and Pichincha provinces. These examples represent only some of the more notable instances of volcanic ash use for the purpose of construction of which enough information has been gathered to draw reasonable conclusions. Many more examples exist but the paucity of information surrounding them would only allow for brief anecdotal mentions.

Conversely, the uses of *cangahua* are far too extensive for the purpose of this thesis and are deserving of an in-depth study of their own. While many of the uses presented here appear to have direct technical functions, some uses are less clear and may represent more obscure ritual practices. In many of these cases, ritual and functional uses may overlap. Though the ritual importance of volcanos themselves may have given all ashes a cultural significance, this chapter focuses on their unique physical characteristics that make them ideal for construction as well as the various methods of procuring, processing, and applying such materials.

The Cangahua Formation: A Pleistocene-age Indurated Volcanic Ash

One of the most common building materials in the northern Ecuadorian highlands, throughout much of the prehistoric past into today, is an indurated volcanic ash or welded tuff known locally as *cangahua*. The discussion of *cangahua* in the geological, pedological, and archaeological literature is sometimes confusing and, at others, contradictory. Part of this confusion may be due to the casual nature with which the term is used. Though the name is given geologically to the Pleistocene-age Cangahua

Formation, it comes from a local term which refers to a wide variety of volcanically produced, weakly-cemented soils. Archaeologists tend to use the term more casually than technically. I sometimes find it useful to refer to these variants of *cangahua* as “official” for the technical term and “unofficial” for the colloquial *cangahua*. It’s also possible that many of the discrepancies in the literature are generated more from differences in terminology and defining attributes highlighted by geologists and pedologists, rather than from extreme variations in the stratigraphic units recognized as *cangahua*.

The Cangahua Formation is attributed to the subarid to subhumid climate of the Pleistocene between 50,000 and 12,000 years ago and is found in deposits sometimes several meters thick throughout the Interandean valley at elevations between 2,400 and 3,600 meters (**Figure 16**) (Hall and Mothes 1997; Quantin and Zebrowski 1997; Zebrowski and Vicuña 1997). The uniform thickness of the Cangahua Formation, despite the variable underlying topography and the high volcanic glass content, indicates that it was likely deposited by a series of eruptive volcanic events rather than produced through a process of differential weathering (Hall and Mothes 1997; Quantin and Zebrowski 1997). Other mineral components of *cangahua* include smectites, hallosites, allophane, and silica, which is more present in areas of more intense rainfall (Quantin and Zebrowski 1997). Organic material comprises less than one percent of its total composition (Hall and Mothes 1997). As such, it is unsurprising that *cangahua* uniquely exhibits both clay-like properties such as compressive strength as well as rock-like properties such as cemented fabric and high tensile strength (O’Rourke and Crespo 1988). The formation maintains the fabric of tuff or consolidated ashfall from which it was formed, though it appears fragmented and modified by weathering (Quantin and

Zebrowski 1997). The unique composite rock and clay properties of *cangahua* results in a highly versatile building material, which has been used as both the primary building material, as well as an earthen mortar, during the past and into today.

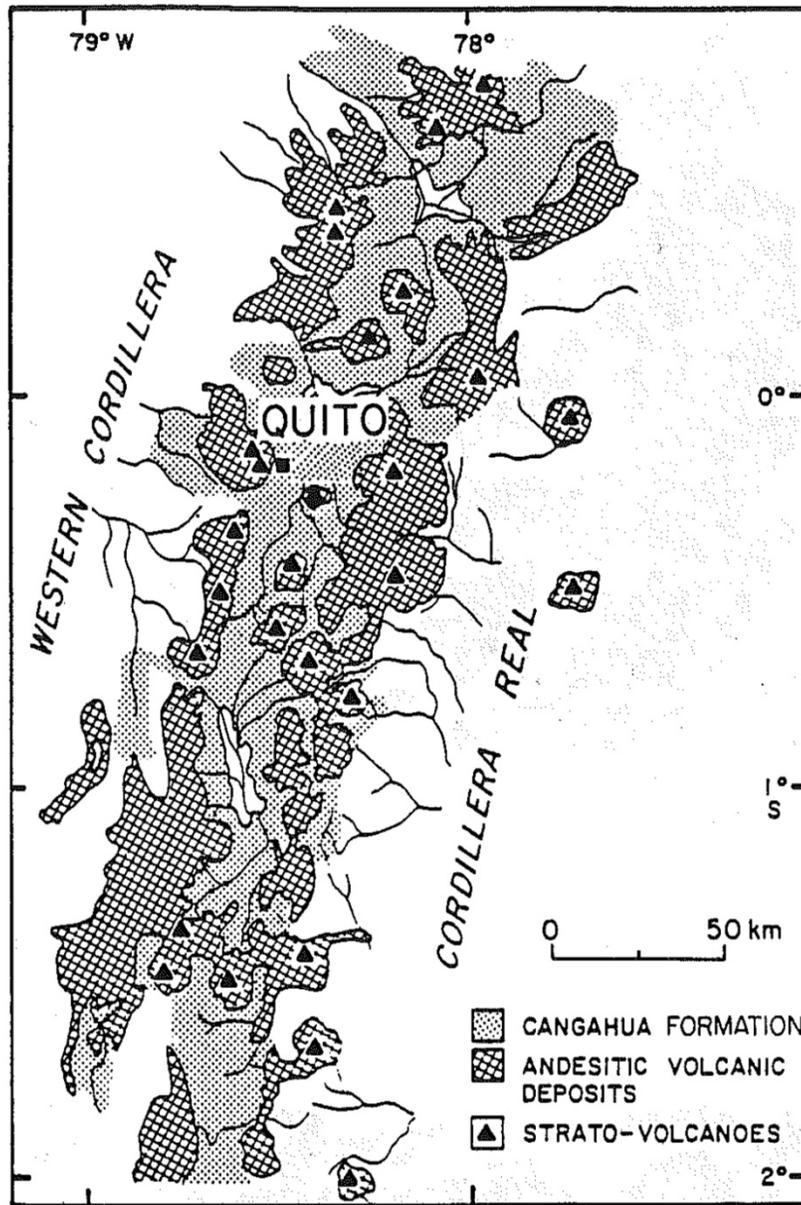


Figure 16: Distribution of the Cangahua Formation within the Interandean Valley (from O'Rourke and Crespo 1988).

While much of the literature on *cangahua* focuses on the effects of weathering on natural *cangahua* formations, a study which is undoubtedly useful for archaeologists

when considering site preservation and formation processes, little attention has been paid to the intentional use and modification of *cangahua*. Some of the unique clay-like and rock-like properties of *cangahua* make it an ideal material for use in construction in a variety of ways. In 2014 at Hacienda Guachalá a dirt bike racetrack was constructed on the hill behind the hacienda. The race track was cut into the underlying *cangahua* formation with a bulldozer to level the track. Hacienda owner Diego Bonifaz mentioned that the cutting of the formation had produced a great deal of dust, but after a particularly hard rain the dust returned to more or less its original hardness and consistency. There are several forms of earthen construction which can utilize *cangahua* and a variety of methods for processing the material to produce the final structures (De Sutter 1984). A contemporary form of construction utilizing *cangahua* known locally as *tapia* involves the mixing of ground *cangahua* with water and vegetal material, which is then laid down in layers between supports to form walls. Brick fragments or ceramic tiles can be placed between these layers as a form of aggregate. Once dried, the supports are removed to leave the completed wall standing on its own. Wetted material with grass or reeds can also be wedged between wooden posts and supports in a style of construction known as *bahareque*. The supports are left in place after the material has dried and hardened. These practices likely have their roots in an ancient practice as many indigenous houses and early colonial haciendas exhibit these types of construction.

One of the earliest historic mentions of the term *cangahua* comes from the 1748 account of the Spanish captains Jorge Juan and Antonio de Ulloa who accompanied the French Geodesic Expedition on their journey to find and map the location of the equator

in the 1730s. Juan and Ulloa noted the manner and material from which houses in Quito were constructed writing:

The material, with which the houses are made, is unburned adobes, and mud, but it is of earth of such good quality, that they have permanence, as if they were made of something more consistent as long as water does not catch them unprotected. They call the earth, of which they make the adobes and then unite them afterwards, Cangagua: it is very hard, and solid, and the Indians used this material in time of their gentility [i.e. pre-Columbian times] for the manufacture of houses, and all manner of walls; of which many vestiges can demonstrate, in the vicinity of that city, as in many other parts of the province, without having been destroyed by time and weather: ample proof of the firmness of the buildings made with it (translation by author).

Juan and Ulloa's description of the use of *cangahua* in Quito suggests that some sort of disaggregated *cangahua*, perhaps after being soaked thoroughly in water, was utilized as a mortar to unite the blocks after they were placed. This conforms with the anecdotal account from Hacienda Guachalá, which indicates that after being ground and mixed with water, *cangahua* reconstitutes itself in a form which is sufficiently hard for the purpose of construction.

It is difficult to pinpoint, but some of the earliest evidence of the use of *cangahua* may come from the site of Cotocollao in Quito where the distribution of postholes indicates possible wattle-and-daub-style construction (Zeidler 2003). The infilling of these posts may have been done with some *tapia*-like material utilizing *cangahua* or

perhaps in the same form as the *bahareque*-style houses. The extensive use of *cangahua* for construction is most widely recognized during the Late Integration Period where blocks of *cangahua*, both shaped and unshaped, were used for the construction of the pyramids. The vast majority of *cangahua* blocks from earthen pyramids are unshaped blocks exhibiting no evidence of intentional modification or rough-cut blocks which are chiseled to a certain uniform size but not into a particular shape. Unshaped blocks appear somewhat randomly distributed throughout the pyramid construction and may be the result of procurement practices as it is often easier to remove large portions of *cangahua* in a single block rather than to grind it into loose fill to carry in a basket. Rough-cut blocks, in comparison, appear to be intentionally laid in poorly organized rows with a form of mortar possibly composed of wetted *cangahua* or volcanic ash (**Figure 17**). These rough-cut blocks have been documented within pyramids at Cara sites such as Puntiachil, Hacienda Zuleta, San Rafael, and Cochasquí (Athens 2010; Cordero 2009; Uhle 1933).



Figure 17: Rough-cut *cangahu* blocks from a pyramid at San Rafael, Ibarra Province (photo by Estanislao Pazmiño)

Cangahua blocks may have also been the primary building material for the structures atop these pyramids. Juan and Ulloa (1748) describe the remains of a circular building on a prominent point near the town of Cayambe composed of unburned brick (presumably *cangahua*) cemented together with the same material as the bricks and measuring eight *toises* (approximately 16 meters) in diameter. They do not indicate whether this measurement is for the interior diameter or exterior diameter of the building.

The walls of the building extend two and a half *toises* in height (approximately five meters) and measure four or five *pies* thick (approximately 1.1 to 1.4 meters). Juan and Ulloa mention that, according to local lore, the area was once the location of a prominent regional temple and this building may have been its extant remnants. It is notable that overlooking the current town of Cayambe is one of the largest Cara pyramids, known locally as Puntiachil, which boasts an upper platform measuring approximately 75 meters east to west by 160 meters north to south and an extended entry ramp approximately 130 meters long. Cara pyramids are often adorned with central circular structures such as those found at Cochasquí, many with diameters that conform to the measurements provided by Juan and Ulloa (see Wurster 1989). Today, a large earthen mound sits atop the center of the platform at Puntiachil and may represent the remains of one of these earthen circular structures. If this is indeed the remains of the structure described by Juan and Ulloa, their account would be the only known description of the construction style of a Cara temple. A relatively simple, nonintrusive way to test this would be to estimate the volume of the mound and compare it to an estimated volume of the structure using the provided measurements, assuming of course that these measurements are somewhat accurate. Given the provided measurements of a diameter of 16 meters, a wall thickness on average 1.25 meters, and a wall height of five meters, we can estimate the volume of material for this structure at 289.56 cubic meters for a 16-meter exterior diameter and 338.703 cubic meters for a 16-meter interior diameter. Photogrammetry generated digital elevation models could reconstruct the volume of the mound at Puntiachil to compare to these numbers accounting for some loss due to disturbance and erosion.

One of the most unique uses of *cangahua* blocks for the purpose of pyramid construction is found at Cochasquí, where large carved pillow-shaped blocks were laid in well-formed rows to compose the stepped tiers of the larger pyramids and as retaining walls to uphold the uppermost platforms. The large blocks are uniformly shaped to a size of approximately 50-by-50-by-50 centimeters and laid into two rows to form a tier approximately one meter in height (**Figure 18**). These rows have been found with small rectangular capping stones laid horizontally across the top. The tiers appear to be relatively uniformly sized and spaced, leading up the slope of the pyramid to the base of one or two larger walls retaining the uppermost platform.



Figure 18: Pillowed *cangahua* blocks forming the lower tiers of Pyramid G at Cochasquí (photo by author).

The blocks of the uppermost portions of the pyramids are much larger than the lower tiers and are composed of three to seven rows of blocks, though these blocks are much more variable in size than those of the lower tiers. The blocks composing each course of the wall were shaped in such a way as to fit neatly atop the underlying course (**Figure 19**) in much the same form as the coursed Inka stone blocks that are documented

throughout the Inka sites in Ecuador such as San Agustín de Callo and Caranqui but have been found in Guachalá and in Quito. A volcanic ash mortar may have been used in some locations to seal the blocks in place (Ortiz Arciniegas 2009). Much discussion has been generated over whether this style of *cangahua* construction is indicative of a unique late Cara development or is the result of Inka construction after the conquest, a discussion which is explored further later in this chapter.



Figure 19: Coursed masonry-style *cangahua* wall from Pyramid G at Cochasquí (from Uhle 1933).

Inka Construction Practices from San Agustín de Callo

The Inka seem to have had a strong practical architectural relationship with the volcanic ash they encountered in Ecuador. In the northern highlands, at the site of San Agustín de Callo located at the foot of Cotopaxi volcano, David O. Brown (2000) noted that all of the natural deposits of very fine-grained ash from the 1280 A.D. eruption of Quilotoa had been mined prehistorically. The Quilotoa ash, found naturally in 8-10-centimeter-thick

layers throughout the site, was taken by the Inka for the construction of their temple at Callo, which became part of a large Augustinian hacienda by the late 16th century (Figure 20). According to the early seventeenth-century historian Antonio de Herrera y Tordesillas (1726 [1625]), after his retreat from the battle of Tiocajas, the Inka general Rumiñawi ordered important Inka sites to be burnt in advance of the arrival of the Spanish. The blackening of the interior walls of the rooms may be evidence that San Agustín de Callo was one of these sites (Brown 2000). Based on tephrostratigraphic evidence, Callo was likely quickly abandoned sometime after the 1534 eruption of Cotopaxi.



Figure 20: Inka Construction at San Agustín de Callo (photo by David O. Brown).

At San Agustín de Callo, the Inka used the fine and compact pozzolana-like Quilotoa ash as a mortar to fill their coursed masonry-style walls, which are visible throughout the site and which have withstood hundreds of years of earthquakes and

volcanic eruptions. Numerous studies have recognized the benefits of fine pozzolana ash materials in the creation of mortar and, perhaps, the Quilotoa ash works in this way (Ezziane et al. 2007; Jackson et al. 2010; Senhadji et al. 2014). Excavations at San Agustín de Callo in 2000 revealed the foundations of an unfinished Inka wall within a well stratified matrix containing two naturally deposited ash lenses including ash from an eruption of Cotopaxi in the 1730s or 1740s, and the 1534 Cotopaxi MZ ash, which seals the wall. The unfinished wall foundation was approximately 120 centimeters wide and is shallowly overlain by colonial materials in some places. **Figure 21** depicts the 1534 Cotopaxi MZ ash and the underlying banded Quilotoa ash lamellae, which represent Inka mortar washed from atop the adjacent Inka wall foundation during breaks in the construction and perhaps after the final abandonment around 1534, marked by the Cotopaxi MZ ash. The presence of the Quilotoa ash bands below the level of the top of the foundation suggest that it was never built higher. The construction style of the wall and the extensive use of Quilotoa ash in its foundation, the key component of the mortar of the classic Inka structures at the site, and as far as we know, never utilized in colonial construction, identify this foundation as Inka. The ash lying atop and to the side of the wall has been identified as the 1534 Cotopaxi MZ ash by local volcanologists Patricia Mothes and Minard Hall. In some cases, this ash still lies atop the unfinished wall, while in others it seems to have been brushed to the side of the wall, suggesting that construction was ongoing during and after the ashfall, but may have stopped almost immediately after. This interpretation indicates that ongoing constructions at Callo may have been halted when the Inka general Rumiñawi on his way north from his retreat from Riobamba, ordered Inka sites south of Quito abandoned and burned.

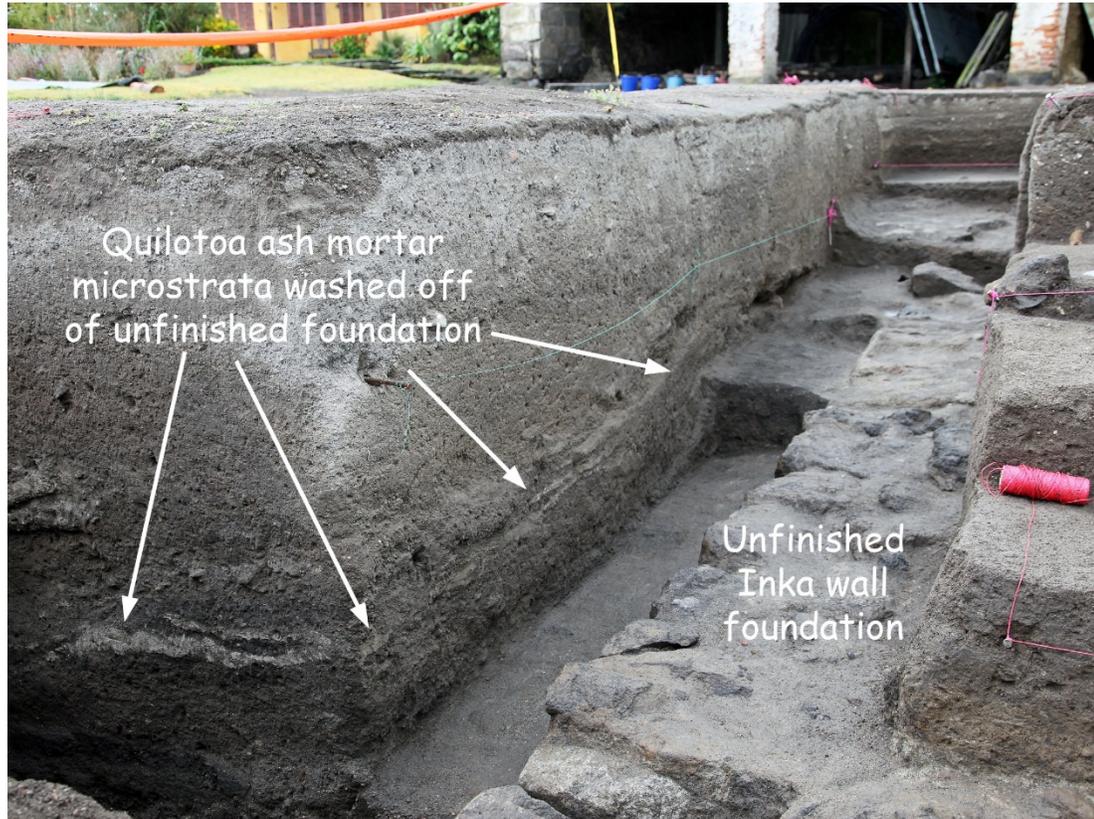


Figure 21: Quilotoa ash washed off of Inka wall foundation (from Pratt et al. 2015).

To create the wall foundations, the Inka architects excavated a setting trench into the underlying volcanic strata, mixed soil and ash fill was then piled up outside the planned wall to create a *tapia*-like form abutting the wall (**Figure 22**). Moist ash mortar fill and rocks were laid into the cavity created by the fill. The wave-like shape of the ash mortar fill lapping up against the previously set Inka fill shows this process clearly. The depression in this fill may have been made by placement of a round-based block in the moist fill. The application of these sediments in a manner that would cause the formation seen in this profile would require mixing them with water and pouring them still wet into the setting trench before placing the next course of stonework. This is a unique construction technique that, as far as we know, has only been documented in Ecuador at

San Agustín de Callo and Hacienda Guachalá, which David O. Brown and I have come to call “wet-laid sediments” (Pratt et al. 2015). Preparing the materials for this style of construction would likely require the excavation of a large pit in which sediments could be poured along with water and mixed. Such a pit would also allow sediments to be floated and sorted and would have helped separate fine Quilotoa ash particles from surrounding sediments after they were mined. This process is discussed in more detail later in this chapter within the section on Hacienda Guachalá where the wet-laid sediment technique was documented in association with such a materials preparation pit.

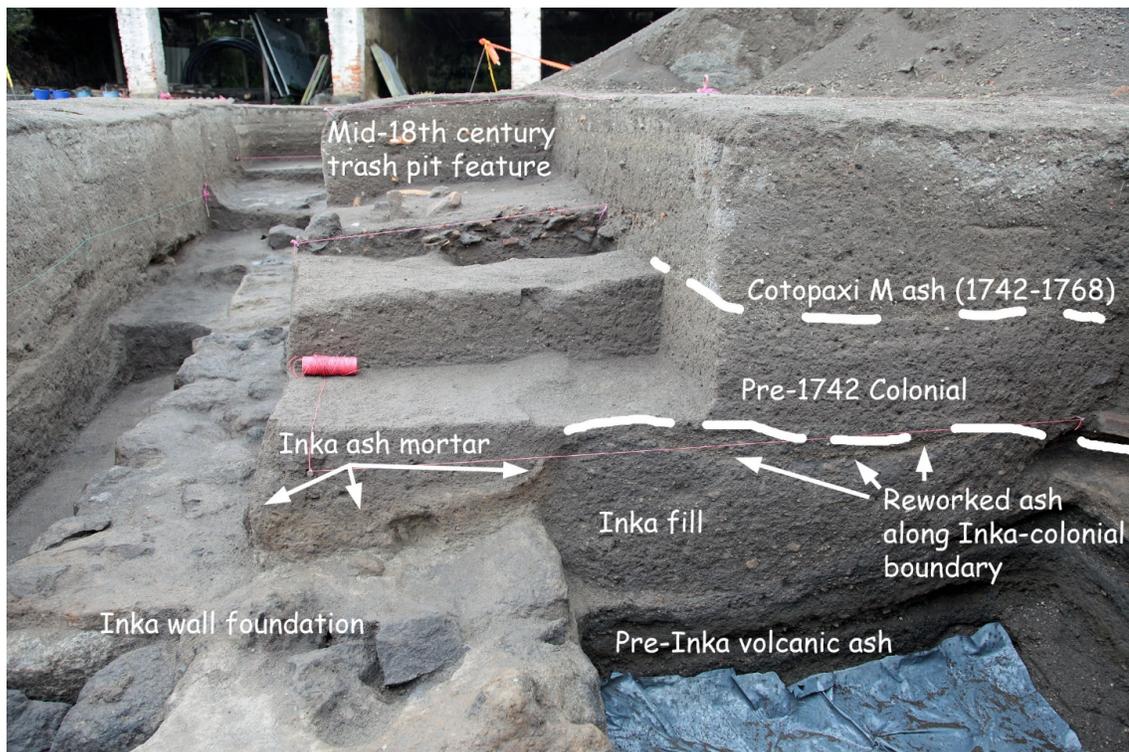


Figure 22: Sediments abutting the Inka wall foundation (from Pratt et al. 2015).

Evidence of the use of Quilotoa ash in wall construction can also be seen within the rooms of the temple complex (**Figure 23**). Excavations within the room that was converted to a Colonial chapel indicated the use of Quilotoa ash as a mortar for the foundations. Unlike Spanish colonial walls, which rarely show structured mortar, these

construction-related microstrata were reminiscent of rock dust layers underlying the fine coursed masonry-style stonework at San Agustín de Callo (**Figure 23**). Thought to have been created by final trimming and fitting of the blocks, this rock dust layer at San Agustín de Callo may have served as a dry lubricant for sliding the blocks into place from earthen ramps at the building corners. The interior of the main Inka wall, while filled with rubble, was largely very fine Quilotoa ash quarried from around the site.

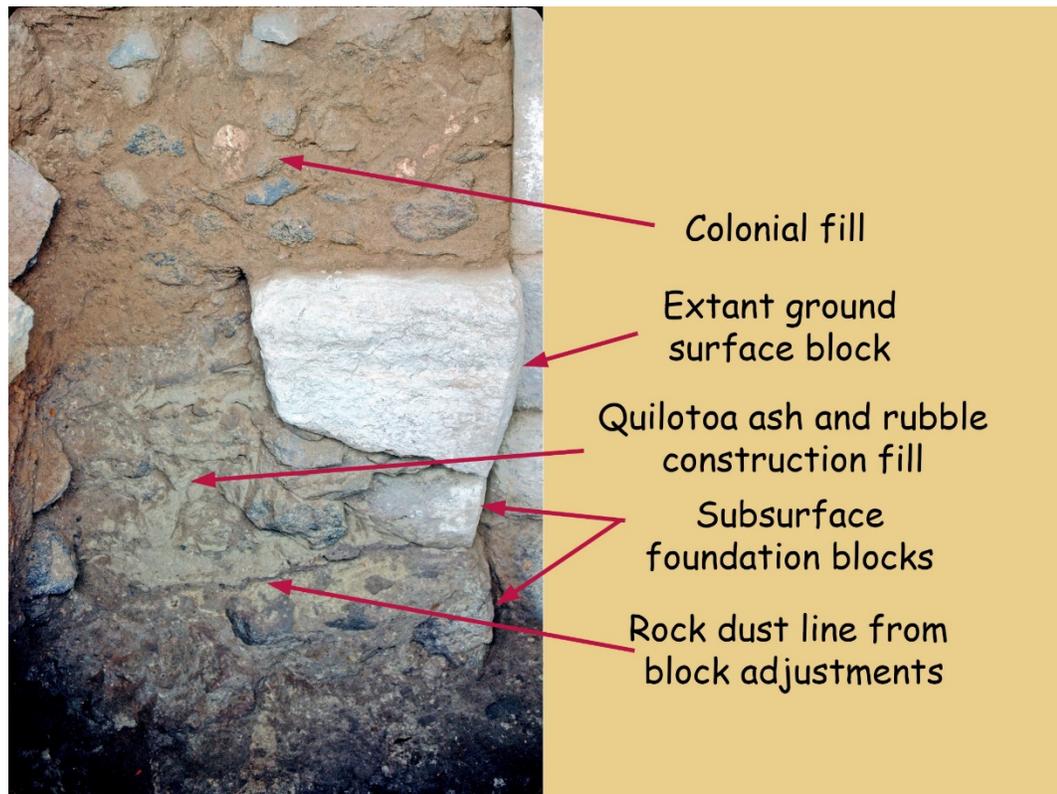


Figure 23: Foundations beneath the chapel at San Agustín de Callo (from Pratt et al. 2015).

A further use of volcanic materials at the site was documented in the form of a pumice layer found underlying the Colonial floor tiles. The underlying pumice acted as a sort of French drain, drawing moisture from the surrounding soil down and away from the floor. The pumice layer beneath the floor may have served another purpose, a contemporary style of eco-house in Ecuador utilizes a layer of pumice beneath the floor

boards to trap in heat and keep the floor warmer than the surrounding air (Mok 2016). This certainly would have been a useful technology at Callo where even today nighttime temperatures can drop below freezing. Though the appearance of the pumice under the floor appears to be a colonial addition to the construction, it may have its roots in ancient Andean practices.

Pumice is extremely abundant in the Cotopaxi region, ancient eruptions of the Chalupas super-volcano located northeast of Latacunga produced deposits measuring 56 meters thick (Toulkeridis 2016). The pumice stone deposits in this region have been exploited and used in construction for hundreds of years likely extending back into prehistory. Pierre Bouguer (1749), the famous 18th century astronomer who accompanied the French Geodesic Expedition to Ecuador, was impressed by the presence of massive layers of pumice-stone in the Cotopaxi region and wrote about them in his account of the journey. Alexander von Humboldt (1883 [1862]) was equally impressed noting existence of pumice-stone mines near the town of San Felipe where mine shafts with large galleries were excavated in order to exploit these deeply buried deposits for the purpose of construction. Von Humboldt stated that many fine buildings in the region were built with the stone and complete blocks twenty feet in length could be removed from these mines. Juan and Ulloa (1748) also noted that many of the buildings in the town of Latacunga just south of Callo were constructed of pumice stone, and that the porosity of the stone allowed the mortar between them to seal them more firmly, which helped them to withstand the frequent earthquakes in the region. The light weight of the stone also reduced the risk of injury should the building collapse. Jean-Pierre Protzen (1983) has suggested that the Inka may have used bars of pumice in order to polish their stones for

coursed- and cyclopean-style masonry. The dense deposits of pumice stone throughout the Cotopaxi region certainly would have made this a viable technique at Callo.

Inka Foundations at Hacienda Guachalá

Lying only a few hundred meters south of the equator in the *cantón* of Cayambe, Hacienda Guachalá, founded in 1580, is touted as the oldest hacienda in Ecuador. Once one of the largest in the region, it has a storied history that extends back to Huayna Qhapaq's conquest of the region. The hacienda is situated along the northern edge of a large cluster of Inka forts known as the Pambamarca fortress complex, construction of which was initiated by Thupa Inka Yupanki during the conquest. The most obvious evidence of the Inka presence at Guachalá is the series of *qollcas*, the characteristic Inka store houses, that lie on a hill southeast of the main hacienda. This line of square buildings, exhibits stream-rolled boulder foundations supporting blocks of Cangahua Formation indurated ash, mixing both local and imperial construction styles. The interior stone-floors are intensely burned supporting local testimony that the site was in flames when Benalcazar's troops arrived in 1534. Several have thick deposits of burned corn kernels dated to the late Inka or early historic period which testifies to the buildings' role in storage (Fries 2010).

Other evidence of the Inka presence includes the mill race behind the hacienda residence. Its construction incorporates several different, non-contemporaneous styles. Most impressive are the massive, well-made blocks that compose the main race. These finely worked stones are in stark contrast to the *cangahua*, adobe, and roughly worked stone of the hacienda's main buildings today. Though the blocks cannot be unquestionably identified as Inka, they were quarried and worked locally and include a

few long specimens thought to be lintels. While the mill race blocks suggest Inka construction, locally quarried, channeled stones, which are a common feature of Inka ritual fountains and baths, are found reincorporated into the Colonial construction leave little doubt as to their Inka origins.

Hacienda owner Diego Bonifaz maintains that the present-day chapel at Hacienda Guachalá is the oldest building on site and was built atop an Inka temple. Between 2011 and 2014, I participated in excavations at the site as part of the Pambamarca Archaeological Project under the direction of Sam Connell, Ana Lucía González, Chad Gifford, and David O. Brown to determine if more evidence of Inka construction could be found. To examine the Guachalá chapel foundations, Trench 1 was dug through the artificial terrace walkway around the chapel in 2011 (**Figure 24**). The trench revealed an earthen and stone foundation atop a natural hill masked by the terrace. The fine-grained earthen “mortar” yielded no colonial materials and the construction appeared to be unlike other colonial foundations at the site and in the region (**Figure 25**).



Figure 24: Hacienda Guachalá 2011 Trench 1 location (photo by David O. Brown).



Figure 25: Trench 1 chapel foundations (photo by David O. Brown).

In 2012 an excavation unit (Unit 2) was placed along the chapel exterior wall north of the 2011 trench. This unit sampled the fill of a room thought to have once been a sacristy. After the cessation of religious rites at the chapel in the early 20th century, the room was expropriated to shear and butcher sheep. Excavations were conducted in the northern portion of the old sacristy where the edge of the terraced walkway meets the wall of the chapel. During this excavation it was noted that where the north wall of the

sacristy abutted the chapel, there was a carved corner stone projecting from the stuccoed wall that suggested a former chapel corner some eight meters south of the current chapel corner. Directly inside the chapel adjacent to this former corner are the poorly preserved remains of a 1757 religious-themed mural depicting Saint Francis with a variety of animals as well as the Spanish monarchs at the time, King Fernando VI and Barbara of Portugal along with several retainers. Both the mural and corner stone align with a change in the type of bricks forming the floor inside the chapel, confirming that the original north end of the chapel had extended only to the north edge of the exterior corner. At some point after 1757, the north wall of the chapel was removed, and the chapel was extended to its current dimensions.

Excavations within Unit 2 revealed an earthen mortar foundation, which was overlain by poorly adjoined rubble filled wall composed of rounded boulders (**Figure 26**). The stone composing the upper portion is very different in both size and character from the lower foundation section which supports it. While the stones seem to be from the same source as the finely cut mill race stone, they are mostly unmodified as is all the observed stonework in the pre-20th century buildings at the hacienda. Not unlike the foundation in the nearby Trench 1, the foundation near the old corner in Unit 2 was composed of as much earthen mortar as stone, and that stone is stream-polished or sub-rounded, identical to the *qolllcas* foundations. The foundation seems oddly disassociated from the overlying wall segment. A closer view of the foundation elements showed thin microstrata between the widely spaced courses of stone. Because this wall supports the interior mural, it must date to 1757 or earlier. Quite likely it was the original wall of the chapel, which is suspected to date to the founding of the hacienda.



Figure 26: Exterior wall foundations near the former corner (photo by David O. Brown).

Initial examination of the laminar microstrata within the foundation suggested the possibility that bands of sediment might have washed in during a period when the foundation was open to the air, perhaps even abandoned. These thin bands were much like the microstrata observed atop the unfinished section of Inka wall at San Agustín de Callo. To further investigate the construction history of the Guachalá chapel and the possible Inka origins of its foundation, Units 3, 4, and 5 were placed inside the chapel in 2014 (**Figure 27**).

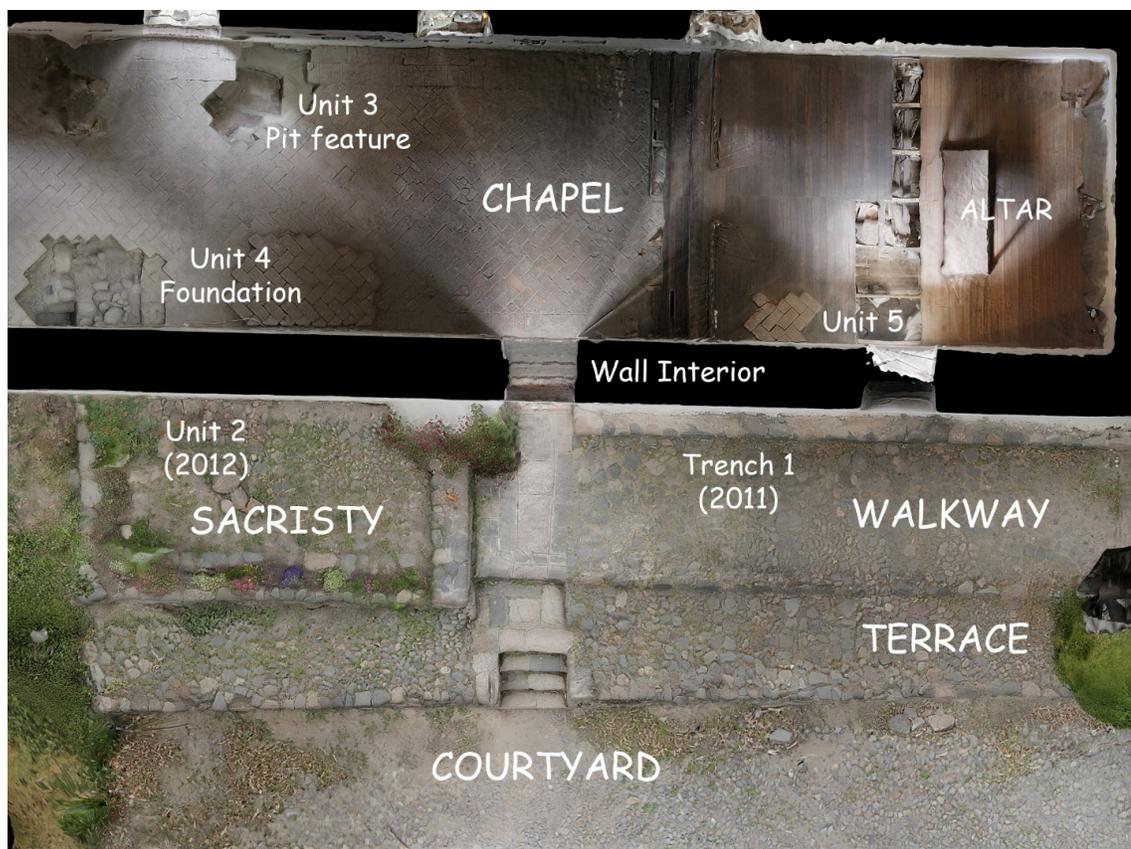


Figure 27: Unit and trench locations within the Hacienda Guachalá Chapel (from Pratt et al. 2015, photo model produced by Mark Willis and Chet Walker).

Unit 5 was placed below the wooden altar floor a few meters south of where the previous trench outside of the chapel had extended to the exterior wall foundation. The interior foundation face was similar to the exterior foundation near the corner with bands of microstrata in association with an earthen matrix. The segment of the foundation exposed by the interior Unit 5 offered a significantly better view of the microstrata, which appear to be an integral part of the construction process, not the result of abandonment or some other construction flaw (Pratt et al. 2015).

Unit 4, placed in the Guachalá chapel interior, uncovered the remains of a wall foundation adjacent to the original chapel corner. This wall foundation likely represents the original north wall that was removed some time after 1757 in order to expand the

chapel. The discovery of this former wall foundation allowed for the examination of construction from a top-down perspective. The still intact foundation was 120 centimeters wide and extended down more than half a meter below the original ground surface at the time of initial construction. Similar in construction to the other sections of the chapel wall foundation found during excavation, the wall was composed of more earth than stone and featured horizontal microstrata throughout its construction. Careful inspection of the layered fill and stones in the wall showed that, in stark contrast to other Inka foundations, and indeed most colonial foundations, the wall matrix had been laid while moist. Platy patterns visible atop the wall were the result of the wet matrix (Pratt et al. 2015). Rock impressions in the top of the wall and the highly deformed, originally flat-laid microstrata also support this hypothesis. Given that its analogue, the unfinished foundation at San Agustín de Callo was very late in the Inka period, the chapel foundation at Guachalá was likely an equally late Inka construction, possibly never finished, and later used as the base for the colonial chapel. A 3D photo model of the chapel created by Mark Willis and Chet Walker (**Figure 28**) allows us to see from above that the former wall foundation seems slightly misaligned with the current chapel, which it supports, perhaps being more properly aligned with the outside terrace wall. This appears to be further indication that the construction of the foundations and the construction of the overlying chapel were completed in at least two different phases by two different builders (Pratt et al. 2015).

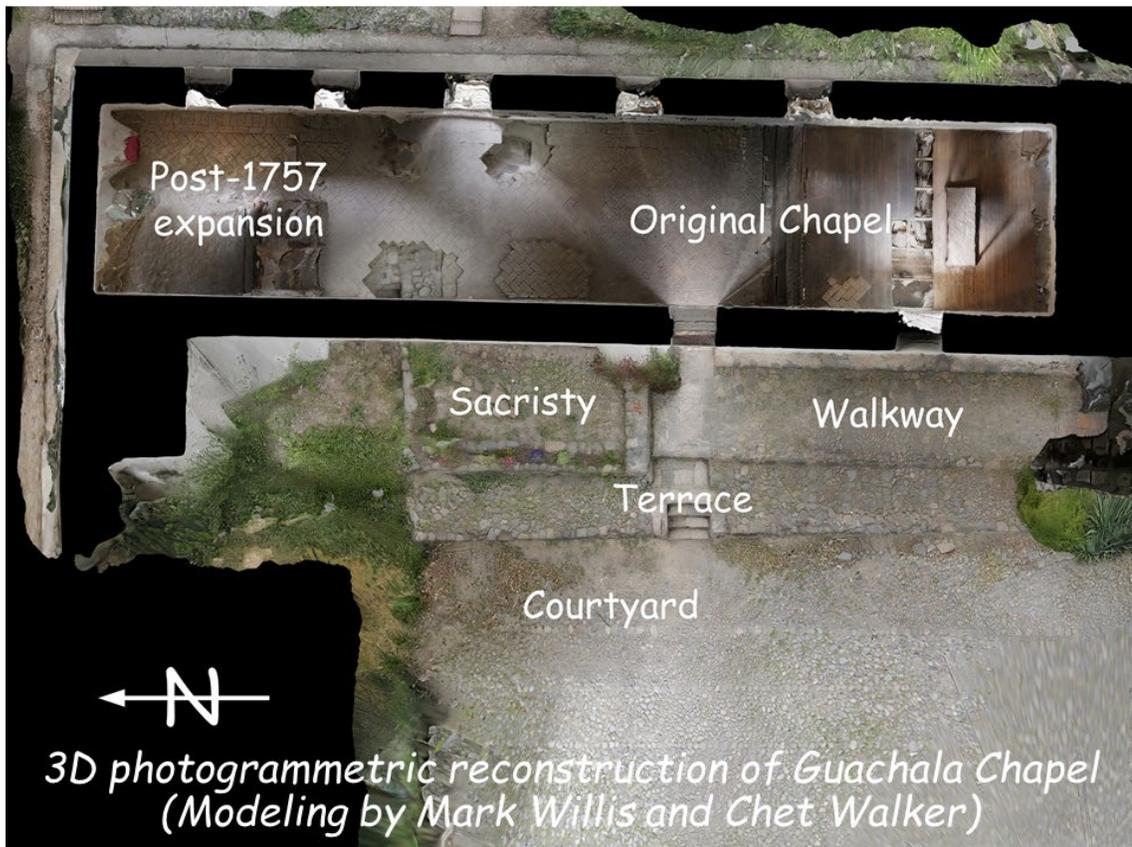


Figure 28: 3D photo model of Hacienda Guachalá (from Pratt et al. 2015).

In contrast to the coarse and poorly sorted Spanish colonial mortars at the site, the suspected Inka mortar is very fine-grained sand with few inclusions. A large pit found in Unit 3 near the original northeast corner of the building may hold a clue to wall construction processes. Initially identified as a burial pit with a stone slab when detected by Ground Penetrating Radar (GPR), it contained no colonial artifacts. A strong reflection detected by the GPR and interpreted as a stone slab was due to the difference in compaction between the loose pit fill and the concave shape of the pit bottom within the underlying Cangahua Formation. Colonial post holes, likely from scaffolding associated with the initial construction of the chapel, cut down into the pit only a short distance. The pit contained a few ceramic sherds in the Late Integration Period Cara style and at least one highly polished possible Inka olla fragment. Near the base of the pit was a unique

sandy zone with abundant ceramics and charcoal. Charcoal from the pit dated to 2000 radiocarbon years BP, a date that corresponds to an eruption of the nearby Cayambe volcano, much older than the pit's Late Integration Period ceramics (Pratt et al. 2015).

Since pure sandy and clayey soils are rare to absent around the hacienda, unlike at Callo where several fine ashes offer suitable mortars, it appears that the pit was used to extract fine-grained construction materials through a slurry and sieving process similar to floatation. This method perhaps allowed the builders to extract the fine grained Quiltoa ash or other fine ash particles from *cangahua*. A discontinuous silty layer around the edge of the pit, not a natural feature, appears as a sort of high-water mark and may have been the end result of this process. In comparison to the crumbly, eroding colonial mortar of the wall above the foundations in Unit 2, the use of such fine sediments with only horizontal bedding planes provided a unique stability to the Guachalá foundation.

The apparent process of wetting, sorting, and mixing materials utilized during construction of the foundations at Hacienda Guachalá is remarkably similar to the process of adobe production practiced in Ecuador. While there is ample evidence that the Inka were familiar with the process of adobe construction further south in Peru, there is no evidence of pre-Inka adobe construction in the northern Ecuadorian highlands as the locals opted for construction using the more readily available and naturally cemented *cangahua*. Contemporary methods of adobe preparation involve first screening the sediments and pouring the fine resultant materials into a preparations pit. The sediments are moistened and mixed either by hand or by foot. Construction of the foundations begins with the excavation of a quadrangular setting trench. Stones are laid into the

trench and a layer of polyethylene is laid over the foundation to keep ground moisture from seeping into the interior of the walls (De Sutter 1986).

To build the foundations at Guachalá, workers dug a preparation pit as well as a quadrangular setting trench for the foundations. Finer sediments were separated from coarser sediments in the preparation pit through a process of flotation and perhaps sieving. After digging the setting trench, a base layer of the extracted fine, wet silt was poured into the trench. A single row of stones, each spaced no more than a centimeter apart from one another at their nearest point, was placed atop this base silt layer. Next, a load of wet, coarser sediments was poured around the stones. Using liquefied sediments allowed the architects to neatly fill all the spaces around the stones without the need for packing the material afterwards. After filling around the stones, another fine, silt capping layer was poured on top of the course of stones. Then a layer of coarser sandy sediment was used to separate the initial row of stones from the next where another base layer of fine silt was laid (**Figure 29**). This process could be repeated as many or as few times as necessary. In fact, it seems that even within the same building different numbers of rows of stones were used in different segments of the foundation with various portions of the foundation exhibiting between two to four rows.



Figure 29: Chapel foundations within Unit 5 showing intentional layering of sediments. Silt layers are indicated by red arrows (photo by David O. Brown).

Layered micro laminated bands like those seen in these foundations are intentional and complex. They require intensive effort and technical skill to produce. They serve no aesthetic purpose, but the nearly impervious bands act as an effective water barrier preventing soil moisture from seeping into the interior of the walls above, serving the same purpose as their modern polyethylene counterpart. Additionally, while baked adobe blocks and lime mortar tend to crack under seismic stress, uncemented fine sediments may be an important adaptation to Ecuador's intense seismic activity. When I was working within the chapel near the end of the field season in 2014, a small magnitude 4 earthquake occurred just outside of Quito in Guayllabamba. The post-1757

portion of the chapel shook dropping bits of debris from the ceiling while the pre-1757 portion of the chapel remained steady giving no indication of the event.

Guachalá, like Callo, appears to have been burned and abandoned just before the arrival of the Spanish. Both the well burned *qolllcas* and the two different construction styles utilized in the chapel seem to support this. The burning at both Callo and Guachalá supports accounts that the Inka general Rumiñawi ordered important Inka sites to be burned before the Spanish arrived. The most obvious evidence that the initial Inka construction was never finished, was visible in the foundations themselves. In some segments, the sediment types change dramatically in the uppermost portion of the foundation. In one location, the top row of stones is set into a fine, well-sorted sediment while covered with a coarse, poorly sorted sand, which is unseen elsewhere in the Inka foundation. Where a foundation stone should have been located in the final course of the foundation, a *cangahua* block was used instead. *Cangahua* blocks appeared in no other segments of the foundation viewed. The block does not rest within the fine silty microstrata as it would if the two were laid sequentially but is instead situated some distance above it suspended within the coarser sandy matrix. In contrast to the coarse and poorly sorted Spanish colonial mortars at the site, the suspected Inka mortar is very fine grained with few inclusions as a product of the careful sieving and sorting process. The evidence supports the idea that the Inka partially completed the construction of the foundations before abandoning the site prior to the arrival of the Spanish. Construction was then completed by the Spanish who erected the building as their chapel.

Both the Guachalá and the San Agustín foundations appear to be a late addition to the Inka architectural tool kit, adding to the notion that the Inka were quick to adopt

new technologies during their expansion. Whatever their origins or history, the Guachalá foundations build on the growing evidence that Guachalá, with its *qollcas*, finely cut stone, ritual water systems, and protected by two nearby fortresses was an important imperial site, perhaps even an administrative center. In the end, Inka Guachalá and the nearby Pucara Chico north of Cayambe, an apparently misnamed agricultural production center, suggest that the Inka consolidation of the area south of Otavalo was already well underway before the final confrontation with the Cara at Yahuarcocha, far to the north.

Earthen Pyramid Construction at Cochasquí

The intentional layering of sediments, including volcanic ash, seen in the earlier shaft tomb and burial mound traditions of the Early Integration Period in northern Ecuadorian highlands continues to be practiced with pyramid construction in the Late Integration Period. Because many of the pyramids and mounds at Cochasquí have been cut or bisected by previous excavations and left exposed, the site offers a unique opportunity to examine mound and pyramid construction without conducting a great deal of excavation. Though Udo Oberem and his crew created many detailed profiles of their excavations at the site, they were more concerned with macrostratigraphic units as evidence of phases of construction rather than microstratigraphic units that represent individual basket loads and may provide clues to technical knowledge or have had imbedded symbolic meaning.

Pyramid G (**Figure 30**) is the largest pyramid at Cochasquí and one of the most severely impacted by recent looting. But the deep trenches and exposed cuts offer the opportunity to examine the construction of the largest pyramid on site from top to bottom without the need for extensive excavations. In the early 1900s, political interest in the pyramid site had grown and officials in Quito began talking about its importance.

German archaeologist Max Uhle was approached to undertake an expedition to investigate the history of the site. When Uhle arrived at Hacienda Cochasquí, he found that the hacienda owners, hearing rumors from the capital of the increased interest in the site, had taken it upon themselves to discover what treasure might lay inside the pyramids. At the time Uhle arrived, Mojanda was still somewhat snowcapped and during certain times of the year a torrent of water came to the hacienda through the site from the peaks above. Uhle discovered that the hacienda had diverted this flow of water through the largest pyramid on site essentially employing a strip-mining technique to carve a huge gorge through the middle of the pyramid (**Figure 31**). Uhle saw the gorge as an opportunity to excavate much of the pyramid in cross section. He eventually exposed from within the remains of some five hundred individuals with no evidence of cranial modification as well as evidence of ritual activity, structures, and various construction styles. Atop the pyramid, Uhle uncovered a long trough-like feature imbedded in an earthen floor, which Uhle interpreted as a canal for some water related ritual. Along the outside of the pyramid, the presence of large *cangahua* blocks was noted forming the tiered façade of the pyramid.



Figure 30: Aerial view of Pyramid G (photo from Parque Arqueológico Cochasquí, drawing from Oberem 1989).



Figure 31: The central corridor of Pyramid G (from Uhle 1933).

Excavation of the gorge through Pyramid G also revealed what has since been referred to as the central corridor, which runs through the middle of the pyramid from the ramp flanked on either side by a two-tiered retention wall of finely formed, coursed masonry-style *cangahua* blocks (see **Figure 19**). Uhle proposed that the finely composed coursed masonry-style walls of the central corridor had joined the façade extending completely around the extent of the pyramid creating high twin platforms in their original composition but that the central corridor had been filled during a later phase of construction. Below this central corridor, Uhle uncovered dense rough-cut block style construction. At the completion of his work, Uhle suggested a chronology for Pyramid G in three phases based on the apparent construction of the pyramid. Phase I of pyramid construction involved the initial construction of the pyramid using the rough-cut blocks Uhle found deep within the gorge. Phase II includes the construction of the upper platforms with the central corridor faced by the coursed masonry-style retention walls. Phase III saw the filling of the central corridor to form a single large platform atop the pyramid with the sacrifice of the recovered individuals to honor the new phase. Oberem (1989) alternatively suggested that, since the Cara practiced cranial modification while the Inka did not, these human remains may represent some form of mass burial to honor those killed during the Inka conquest of the site. Given the similarity in form, Uhle concludes that the upper retention wall had been constructed by the Inka after their conquest of the site. Uhle uses his interpretations of stratigraphy, Inka masonry style, and etymology to support his claim. Cochasquí, Uhle points out, is a conflation of Cara and Quechua terms with “*cocha*” being Quechua for “lake” or “body of water” perhaps

referring to the crater lakes above the site and “*qui*” or “*ki*” meaning “place” in the local Barbacoan dialect.

Wolfgang Wurster (1989), who excavated alongside Udo Oberem, disagreed with Uhle’s interpretation, suggesting instead that the pillowed form of these blocks is not necessarily the result of Inka construction style. The shape of the blocks, Wurster argued, was simply due to the fact that large blocks were easier to remove and transport. Wurster proposed that these stepped walls forming the lower tiers of the pyramids were simply retention walls which were meant to be covered by loose fill after their installation. This assessment is based primarily on comparisons with other Cara sites where unshaped blocks have been found forming retention walls within pyramids (Athens 1980) as well as on the observation that *cangahua* can be easily eroded if left exposed to the elements.

However, a *cangahua* block a quarter of a cubic meter in size is not easily transported and ensuring that all the blocks are approximately the same size would require a level of coordination that would not be necessary for the construction of retention walls. The rectangular capping stones found intact in some locations atop the tiers serve no real purpose as part of the retention wall but instead seem to be cosmetic, providing the top of the curved pillow-shaped blocks with a flat, even surface. The coursed masonry-style retention walls that form the uppermost tiers surely would have taken much energy to shape and fit. Thus, it seems odd that the builders would expend such effort to subsequently cover these fine walls with loose earth. Additionally, the tiers composing the pyramids at Cochasquí are very uniformly sized and spaced appearing to cover all four sides of the pyramids while true retention walls are placed opportunistically only where they are deemed necessary.

As to the issue of preservation of *cangahua* blocks, I have visited many open archaeological sites where *cangahua* has lasted exposed for well over a decade without any maintenance. The *cangahua* blocks on display at the park today were left exposed after Oberem's excavations for several decades until the park erected tin rooves to help preserve them. It's possible that *cangahua* blocks would have been preserved for much longer during the cooler and drier climate of the Little Ice Age the effects of which began in Ecuador at approximately 1250 AD and lasted until sometime between the mid-1700s and early 1800s (Heine 2011; Ledru et al. 2013). Widespread industrialization in the 1900s would have increased the occurrence of acid rain, which can impact soil structure, especially of alkaline rich soils such as *cangaua*, so contemporary comparisons of preservation may be skewed. If the circular structure described by Juan and Ulloa really was the remnants of an ancient temple built from *cangahua* blocks, then it would have been left standing without upkeep for at least 200 years from the arrival of the Spanish until the French Geodesic Mission's visit in the 1730s. Furthermore, constant upkeep and periodic additions to the pyramids would have made erosion of *cangahua* less of an issue for the population maintaining them. *Cangahua* walls may also have been covered by a layer of fine silt stucco-like material to protect them. Such a material was found in 2009 by the Pambamarca Archaeological Project covering the tiers of the small Loma Sandoval pyramid near Hacienda Guachalá (David O. Brown personal communication 2017).

While it has been suggested that Cochasquí was abandoned after the Inka conquest, Albert Meyers (1976) has noted that there are significant quantities of Inka ceramics on the surface of every single pyramid at the site which he suggests indicates

that the Inka were performing rituals atop the pyramids after the conquest. Excavations conducted by Oberem and his crew at Cochasquí found the coursed masonry-style construction within Pyramid E and pillowed blocks forming the stepped tiers of Pyramid M (Wurster 1989). Lenin Ortiz Arciniegas (2009), the park director at Cochasquí between 1981 and 1986, writes that white volcanic ash was used as a mortar to seal these blocks. Though Ortiz Arciniegas was not an archaeologist, he spent many years at Cochasquí, and the exposed excavations would have given him more time to examine the walls and their construction than any archaeologist who has worked at the site. The fact that the coursed masonry-style *cangahua* walls formed by pillow-shaped blocks have been found at no other location besides Cochasquí, that Cochasquí was the first major Cara center to be conquered by the Inka, which would have provided them more opportunity to interact and exchange building practices, and that the blocks appear to compose only the final phases of construction at the site, indicates that these coursed masonry-style *cangahua* block walls may indeed be the resultant combination of Inka construction style and local building materials. As has been observed, the Inka were famously quick to adopt local building practices and incorporate local practices throughout numerous regions of their empire. At the very least, it seems more likely that this style of construction is the result of some form of Inka influence than it does to be some independent Cara development.

Recent Excavations at Cochasquí

In 2017, I began examining some of the exposed profiles within one of the trenches created by the hacienda extending from the central gorge excavated by Uhle into the western portion of the pyramid. I have dubbed this trench “the western cut” which is

visible in the previous **Figure 30**. The depth of the trench varies between two and four meters below the uppermost platform of the pyramid and it exposes some of the final phases of construction. I was able to clean a three-meter-deep profile within this cut and examine some of its structural components. In 2018, I conducted a series of excavations at the base of this same profile in order to extending this three-meter-deep profile a further two meters below the surface of the pyramid.

Two buried earthen floors and a possible buried surface were also exposed during the profile cleaning and excavation. The buried surface is found approximately 30 centimeters below the extant pyramid surface and likely represents one of the final uses of the pyramid. One earthen floor was found 2.3 meters below the pyramid surface within the exposed profile while the other was discovered during excavations at the base of the profile approximately 3.4 meters below the pyramid surface. The earthen floors appear to have been prepared especially for construction of a structure, evidence of which is seen in the uppermost floor in the form of two postholes extending below the floor as well as in the form of chunks of *cangahua* near the upper extent of the postholes which likely representing the base of the since-destroyed walls of the structure (**Figure 32**). Several large *cangahua* blocks were found scattered across the lowermost floor and are likely the result of the demolition of a structure associated with the floor but not directly encountered during excavations. The largest of the *cangahua* blocks atop this floor bears tool marks across its broadest face which appear to have smoothed the face of the block indicating that it is indeed a carved block meant for construction and not simply rubble fill (**Figure 33**).



Figure 32: Earthen floors exposed within the western cut profile indicated by red arrows. One of the posthole features can be seen clearly in the upper floor just above the left corner of the excavation unit (photo by David O. Brown).



Figure 33: Carved *cangahua* block from atop the lower earthen floor (photo by author).

The earthen floors exposed in the western cut, which appear much like a floor described by Max Uhle during his excavations near the surface of the pyramid, are formed by a mixture of sediments including clayey loam from the high elevation grasslands above 3,600 meters known as *paramo*, reconsolidated *cangahua*, and the addition of other clay materials likely from the Pisque River valley to the south. The unique cracked structure of the floor is likely due to shrink-swell properties and indicates a relatively high clay content not seen in other sediments throughout the site. The acquisition of such clay must have come from intentional transport of clay materials from deposits far below the elevation of the site in the Pisque River valley to the south or the processing of the clay-rich *paramo* soils. The well sorted nature of the sediment comprising the floor indicates that the materials were likely sifted before being intentionally mixed together, likely within water, and poured onto the surface, not unlike that seen in Inka constructions at Callo and Guachalá and possibly a technique learned by the Inka during their occupation of the north.

This begs the question: Where could such a quantity of materials necessary to cover large portions of the pyramid be mixed? The pyramids at Cochasquí are surrounded by many large depressions in the ground surface where the majority of materials were mined for construction of the pyramids, so called “borrow pits.” Even today during the rainy season these depressions fill with and hold water. There is no apparent way for these depressions to quickly drain unless a yet undiscovered system of now clogged drains exists underlying the depressions. In fact, dual features extending uphill from the back corners of the two largest pyramids, which have been described as “back ramps,” would have formed sort of dams on either side of the depressions directly behind the

pyramids and may have been intended to form catchment ponds. The creation of catchment ponds to collect water has been documented ethnographically around Cochasquí and was a common method of preparation for the dry season during the hacienda period (LCQ 1934 [1534-1543]; Ortiz Arciniegas 2009). The Quechua word for lake embedded in the name Cochasquí may refer to the presence of these ponds around the pyramids. The apparent reliance on catchment ponds around Cochasquí in the Late Integration Period may have been an adaptation in the drier post-Quilotoa environment. If these borrow pits were not intended to be filled with water, then their appearance is somewhat perplexing as they surely would have caused a headache for the local inhabitants for months out of the year without some drainage system. Saturation can be extremely destructive for *cangahua* and has been identified as one of the primary causes of degradation at the site (Manaresi and Pellizzer 1979; O'Rourke and Crespo 1988). On the other hand, if the filled depressions were intentional, they may have held symbolic significance, been associated with water related rituals, and could have also provided a large enough pool for material preparation and processing during construction much like the materials preparation pit documented beneath the floor of the chapel at Hacienda Guachalá.

In addition to the borrow pits, a large depression can be seen just north of Cochasquí, which measures 0.5 by 0.75 kilometers. This depression, while dry through most of the year, still holds some water today during the rainy season and drains via a heavily eroded canal travelling directly through the monumental center of the site. This canal was recorded in the 1930s by archaeologist Max Uhle as a river, attesting to the quantity of water which it carries at certain times of the year and, indeed, white water can

be seen in his photos flowing within the quebrada that passes through the site (Uhle 1933). One of the earliest historic mentions of Cochasquí in the Cabildos de Quito documents a request during a townhall meeting by one of the Spanish landholders to dam the canal which drains a nearby lake, likely referring to this feature (LCQ 1934 [1534-1543]). A dense quantity of early colonial ceramics found where the canal drains the depression may represent this early attempt to dam the lake. The presence of such a lake may also have been partial justification for the name Cochasquí.

Materials found atop the buried clay floors hint at the time of the year during which construction might have taken place. Ritual structures in the Andes are kept meticulously clean and it is unusual to find refuse associated with them. Yet many burned bones including *cuy* (Guinea pigs) and llama as well as fine burned ceramics are found mixed within the fill layer directly atop the floors. As this refuse was unlikely to be left atop these floors during their occupations, it seems to be evidence of some final event which took place shortly before the floors were buried. Most notably, a large number of land snail shells were found, likely *Naesiotus quitensis* which have been documented at archaeological sites in the highlands and are eaten locally during certain times of the year (Stahl 2003). The locals at Cochasquí maintain that the snails are only harvested between December and January and that they are not found at the elevation of Cochasquí but must be collected from lower elevations. These snail shells are also found in large quantities in earlier feasting or offering pits throughout the region, a testament to their association with ritual feasting events. Cuy, as well, is traditionally only eaten during particular ritual feasts.

The rainy season at Cochasquí occurs sometime between October and December, just before the period in which these snails are eaten. This might suggest that feasting activities associated with the construction of the new phases of the pyramid were taking place at the end of the rainy season and the initiation of the dry season when the catchment ponds and lake might have been filled to the highest level. The water collected within the lake and the catchment ponds could have been used for the mixing of materials on a scale necessary to produce the sizeable clay floors. This would have been the perfect place to conduct the large-scale mixing of materials necessary to produce the floors in a way that would increase the ease of homogenizing the mixture or, as in the case of Hacienda Guachalá, could have been used to separate lighter sediments including volcanic ash from the denser sediments within the matrix. It also would have allowed for the creation of the wet *cangahua* or volcanic ash mixture that could have been used as a mortar for the early rough-cut block construction of the pyramids. Water appears to have an integral part of many earthen construction techniques as evidenced by the number of early techniques that relied on wetted sediments outlined earlier in this chapter. Thus, methods of capturing water may have been necessary for the purpose of construction as well as agriculture.

The uppermost floor within the western cut profile was covered by a uniform ten- to fifteen-centimeter-thick pumice-rich layer (**Figure 34**). This layer extends across the trench into the opposing profile, indicating that it was intentionally laid across the entire buried surface during the new phase of construction and was not the result of basket loads which would appear layered and interfingered. This uniform layer may have been laid as some form of ritual termination to prepare the old surface for new construction. Above

this pumice-rich layer, basket loads of darker sediments and lighter pumice were laid during the new phase of construction. Sediment layering consisted of very dark grayish brown (10YR3/2) layers of sandy reconsolidated *cangahua* interspersed with grayish brown (10YR5/2) layers of sand and coarse white pumice, likely from one of the early Pululagua eruptions that comprise between 50% and 90% of the layers (**Figure 35**). The composition of the reconsolidated *cangahua* and pumice gives the appearance of intentionally alternating dark and light layers. Similar dark and light alternating sediments were documented by grupo del trabajo Ecuador within the uppermost portion of the profile of Pyramid L and likely correspond to those exposed within Pyramid G (**Figure 36**).



Figure 34: Pumice and *cangahua* chunk dense layer (indicated by the red arrow) covering earthen floor (photo by David O. Brown).



Figure 35: Alternating dark and light sediments exposed within the western cut profile of Pyramid G (photo by David O. Brown).

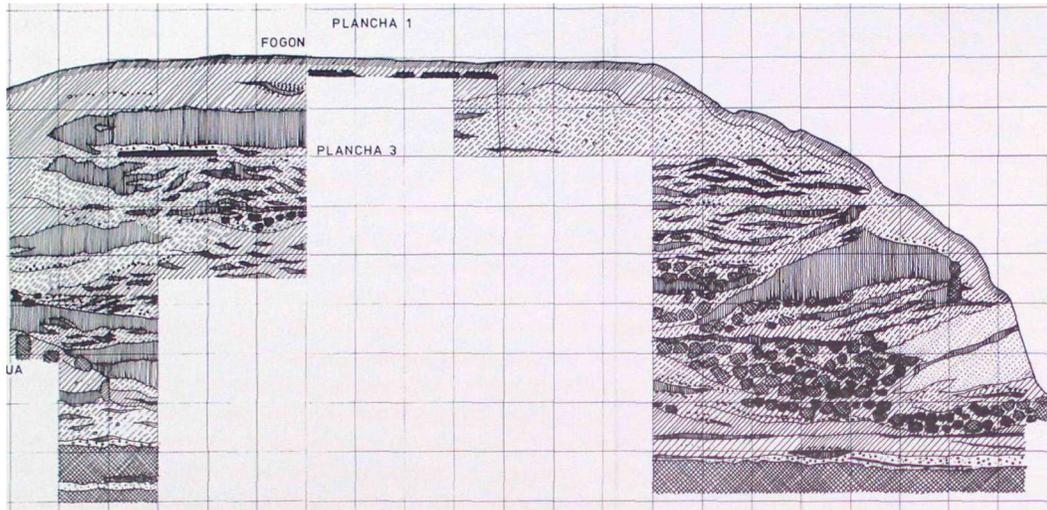


Figure 36: A portion of the Pyramid L profile documented by grupo del trabajo Ecuador (from Wurster 1989).

The pumice-dense layers within Pyramid G are composed of relatively coarse white pumice from deposits that have not been documented on site. Only three naturally occurring volcanic ash layers have been documented at Cochasquí. One, composed of very fine white ash from an unknown eruption, is found overlying the uphill portion of

Mound x but has been seen in no other portion of the site. The other two are composed of coarse-grained gray pumice that are found in 20-25 cm thick layers a few meters below the extant surface, likely from the 690 BC and 450 BC Pululahua eruptions. Thus, the pumice material utilized within Pyramid G appears to have been collected from some unknown location and may not be the result of some least cost procurement practice. However, as has already been observed, the absence of corresponding natural ash layers does not necessarily indicate that such layers were not present. Corresponding layers may have been completely mined throughout the site specifically for construction of the pyramids or may have come from deposits within the river valley below. The Inka mined much of the natural Quilotoa deposits around San Agustín de Callo, for a for the creation of much smaller structures. Locals still mine the pumice deposits exposed along the Pan-American highway in the Pisque River valley to the south primarily for the production of cinder blocks leaving small alcoves, which can be seen scattered along the roadway. In either case, it is notable that only the white pumice was selected for use within the pyramid while the great quantity of available gray Pululahua ash, which was certainly known due to its appearance in Mound x, seems to have been disfavored. This, coupled with the fact that these layers comprise only the uppermost portion of the pyramid with sediments two meters below the upper platform consisting largely of reconsolidated *cangahua*, might indicate that their presence is not due to some accident, but rather intentional architectural design.

Additional alternating layers of clayey loam from the *paramo* and sandy pumice dense layers are seen in other exposed portions of Pyramid G. Wolfgang Wurster (1989) documented these layers as “dark clay” or “chocoto” that was used as a mortar to hold the

carved *cangahua* blocks in the coursed masonry-style walls along the face of the pyramid in place. If these layers were indeed meant as mortar for the adjoining wall and if the carved blocks are an Inka addition to the site, then the alternating dark and light layers behind them were likely an addition to the pyramid during the Inka occupation. While the reasoning behind the choice of the clay rich *paramo* sediments as mortar for the blocks is clear, it is less clear why the loose, pumice dense sand was chosen. The choice might attest to the compactive and bonding nature of such sediments. The addition of pumice and volcanic ash may have served as an aggregate to bond the sediments and increase the overall compaction as is done in contemporary construction (Harichane et al. 2012). Such a use is not without precedent. Stone blocks at the Inka fortress of Rumicucho, just across the Guayllabamba River valley from Cochasquí, were laid with clay and pumice gravel mortar to bond them (Echeverría Almeida 2004). However, in the case of the alternating layers exposed in the western cut and those of Pyramid L, there is no *cangahua* wall directly associated with these alternating layers to explain their presence and there may be no technical purpose for their addition.

Because ashfall is naturally sorted, with larger grain sizes falling closer to the eruption and smaller grain sizes falling further away, the relative size of ash and pumice can be used to determine whether pumice layers are naturally or artificially deposited. Like alluvial deposits, pumice and ash are self-sorting with larger, heavier grain sizes falling first before lighter sediments are deposited on top. The range of pumice grain sizes seen in the west cut profile indicate that they may have been collected from different ashfall sources. Thus, the builders of the pyramid appear to have gone to great lengths to find white pumice deposits from different locations specifically to incorporate into the

pyramid. The alternating layering of basket loads of white pumice and darker sediment appears to have been intentional meant to produce the appearance of alternating dark and light layers. Alternatively, it may have been the product of some organizational characteristic during construction such as two different groups of builders working concurrently, one group of builders gathering material from one location and another gathering material from a different location, perhaps bringing the materials from their respective villages. This would certainly fit with the community organized workflow demonstrated in local *mingas*. If this is the case at Cochasquí, then it could hint at the range of influence the site maintained over the neighboring villages. In either case, given the mix of grain sizes seen in the pumice-rich layers, it seems unlikely that they were gathered at one time from the same location and the sheer quantity of volcanic pumice present within these layers in the upper portion of the pyramids indicates they are the product of intentional inclusion. The fact that natural coarse pumice deposits would require excavating one to two meters below the surface, suggests that simply accessing these deposits would have required a targeted effort. Thus, the intentional layering of pumice and sediment seen in the final phases of construction of Pyramid G and Pyramid L seems to have been a conscious decision on the part of the architects who perhaps intended for the layers to provide some symbolic meaning to the construction. But what sort of meaning could be engrained in intentionally layered sediments?

A Comparative Case in the Southeastern U.S.A.

While intentionally layered sediments are seen in many parts of the Americas, it may be useful to look to the Mississippian mound builders in the southeastern United States as a comparative case. Mississippian mound building is contemporaneous with Cochasquí, the

mounds are built with the successive layering of sediments, and small hemispherical mounds were built in the earlier phases before large truncated pyramids became more standard. The intentional layering of sediments is well studied in Mississippian mounds with one particularly famous article referring to the Mississippians as the *Da Vincis of Dirt* (Sherwood and Kidder 2011). The Mississippians chose clay as a primary building material for its association with the creation myth and used different colors clays for their association with colors in Mississippian cosmology. Materials were also chosen not just for color and consistency, but also for the locations on the landscape which they were seen as representing. Clays found in river bottoms were symbolic representations of the watery Mississippian underworld. As such, the choice of source, color, consistency, and layering of clays appears to have been an extremely conscious decision with a great deal of inherent symbolism related to cosmology. Monk's Mound, the largest of all Mississippian mounds is especially interesting as a comparative example, as portions of Monk's Mound appears to have been built using alternating layers of dark and light sediments (**Figure 37**) (Sherwood and Kidder 2011).



Figure 37: Alternating dark and light layers from Monk's Mound, Cahokia, U.S.A. (from Sherwood and Kidder 2011).

So how then might we begin to understand the symbolism that may be engrained in the choice of fill used and the layering represented in pyramid construction? In Ecuador, the intentional layering of sediments is also seen within the earlier shaft tomb and burials mound traditions. The alternating layers of sediments within the pyramids appears to be a continuation of these practices. Builders seem to have been very conscious about what materials were used where and may have been under constant direction. More careful documentation of sediments within shaft tomb, earthen mounds, and pyramids is needed to untangle these mysteries. Archaeologists should focus not only on macrostratigraphic sequences associated with building phases, but also on microstratigraphic sequences associated with individual basket loads, sediment processing, and the different locations on the landscape. The use of these sediments within the pyramids intimately links these locations on the landscape and their

communities as well as their various environments, agricultural products, and lifeways to the ritual aspects of the pyramids. Like Mississippian mounds, the pyramids were meant to serve as temples and cosmologically linked intentional layers may have been a necessary facet of their construction. Perhaps the same sorts of symbolic information are engrained in the pyramids as are engrained in Mississippian mounds and real clues to the cosmological beliefs of the people that built the pyramids may have been literally laid out before us.

The Volcanic Ash Canal of Rumipamba

Another somewhat anomalous use of volcanic ash appears at the site of Rumipamba in Quito. Rumipamba is a poorly understood Integration Period site located on the eastern slope of Pichincha volcano. A mix of cultural material from different time periods can be seen at Rumipamba including *pirca*-style Inka terrace walls that have been incorrectly interpreted as associated with the early habitation of the site, which was destroyed and abandoned after the 1660 AD eruption of Pichincha volcano. Of interest at Rumipamba is a single canal-like feature formed completely of volcanic ash (**Figure 38**). My initial assessment of this feature was that it must have been naturally formed and just happened to take the appearance of a canal or was accidentally carved into this canal-like form during excavations. However, volcanologist Patricia Mothes (personal communication 2018) has examined the feature closely and insists that it is not the result of natural ashfall, but rather is some feature constructed of reconsolidated volcanic ash from an unknown eruption, perhaps an ancient eruption of Cotopaxi volcano. The exact use of such a feature is unclear as it does not appear to be linked into any extensive canal system and the force of passing water would have likely put significant wear on the fine ash

feature though ash may have composed only a small segment of a much more broad system composed of other materials. Perhaps it was related with some unknown water related ritual in which liquids were poured into the canal or was constructed for some sort of firing or smelting process. Only more extensive excavations at the site could answer these questions, but the existence of such a feature demonstrates the flexibility that the unique properties of volcanic ash provide for the purpose of construction.



Figure 38: Canal-like volcanic ash feature at Rumipamba (photo by author).

Results and Discussion

As mentioned previously, the relatively consistent year-round rainfall in the northern highlands near the equator prevents the formation of clay rich B-horizons (Minc et al. 2016). Given the lack of widespread clay deposits suitable for mortar, it's unsurprising

that the people of the northern highlands turned to volcanic ash, with its unique chemical and physical properties as a suitable substitute. The unique properties of fine-grained volcanic ash allow it to be wetted and reconsolidated in a form that hardens to provide a secure structure as mortar or, in the case of Rumipamba, as a sort of concrete. In locations where ash lenses exist in centimeter or sub-centimeter thickness, collection can prove difficult and specialized processing methods such as those documented at Hacienda Guachalá must be implemented to remove them and separate them from the surrounding sediments.

The *paramo* soils generally exhibit between 10 and 30 percent clay content which may have made them suitable mortars especially with the addition of other materials or if they were disaggregated in water before their application (Zethener et al. 2003). The addition of pumice to these sediments could serve as an effective aggregate increasing cementation and compaction. The fact that this method is used at the Inka fortress of Rumicucho and for the coursed masonry-style walls at Cochasquí suggests that this may have been a practice of the Inka who were known to use clays extensively in construction, especially as mortar. Where clay or fine volcanic ash are in short supply, disaggregated *cangahua* may have served as a substitute particularly if they have been sifted or sieved to separate the fine clay minerals such as halloysite.

Just as volcanic ash likely served as a suitable substitute in a region with few clay deposits, so too does *cangahua* serve as suitable substitute in an area where consistent rainfall leaves few unfragmented rock outcrops. Though early Inka construction appears to favor the use of stone, later structures were built largely with *cangahua* reflecting more expedient construction techniques or an incorporation of local building practices.

Cangahua offers the advantages of being readily available, easily shapeable, and a source of potential mortar as well as blocks. The increased use of *cangahua* from the beginning of the Integration Period into the Late Integration Period coincides with evidence of increased social complexity and organized ritual activity seen in the monumental architecture that emerges in the northern highlands. It is notable that the majority of construction techniques which utilize *cangahua* and volcanic ash appear shortly before the arrival of the Spanish. The appearance of construction techniques utilizing volcanic ash as mortar and additives as well as the sifting and sieving techniques implemented for wet-laid sediments is likely associated with the need for a wide variety of new techniques to accommodate monumental architecture. But the increased use of volcanic ash may also be due in part to the intended ritual function of the monuments. While ash layers appear prominently within the shaft tombs and hemispherical burial mounds, they largely appear in only a few deliberate strata. Volcanic ash makes up a far greater portion of the pyramids and collecting white ash in such large quantities when natural *cangahua* deposits were readily available immediately adjacent to the pyramids surely indicates the importance of including such layers either for technical or symbolic purposes. As has been observed, pyramid construction begins after the 1280 AD eruption of Quilotoa and it has been suggested that such monuments were erected in an effort to appeal to the gods after the widespread devastation and the onset of the drier post-Quilotoa climate (Echeverría Almeida 2004). In this case, the broad scale use of white volcanic ash within the pyramids may hint at their intended symbolic function, namely their association with volcanos and the life-giving-waters, both in the form of precipitation and glaciers, which they command.

IX. CONCLUSIONS

The cases presented in this thesis make clear that there are a number of ancient uses for volcanic ash that vary by region, culture, and time period. By further examining these uses, they can become regionally, temporally, and culturally diagnostic features in the archaeological record allowing us to attribute specific artifacts or features to a specific time period or culture despite any lack of other datable or diagnostic materials. The ability to source and date the constituent ash to a particular region and volcanic eruption allows us to create hypotheses about areas of impacts, cultural responses to environmental disasters, and systems of exchange. The various ways in which volcanic ash appears to have been used hints at the level of recognition that these ancient people had for the effects of the volcanos and the complexity of their connections to these natural features of the landscape.

Though the relationship between volcanic ash and fine kaolinite clay sources was likely unrecognized by the ancient people of Ecuador, the weathering of ash deposits produced highly desirable clays that are still used in ceramic production today. Contemporary cases make clear that even if a fine highly vitrified final product is not necessarily desired, the material can be added to other types of clays to strengthen them. In regions where clay deposits are scarce such as the northern highlands, more studies are needed to determine the relationship between the natural ash content of clays, the properties of these clays, and their desirableness with local potters. Though represented by only a single case, the Los Soles kiln makes clear that there was at least some recognition amongst the people of the Formative Period that volcanic ash had heat resistant or insulating properties which could be utilized for the purpose of firing

ceramics. Perhaps the odd volcanic ash canal-like feature from Rumipamba was also constructed for its heat resistant or insulating properties.

Volcanic ash traded over long distances as in the case of Guangala polychrome ceramics could potentially be identified and sourced to draw broader conclusions about the connections between the people of the gulf of Guayas and the highlands. The fact that *Spondylus* shell items appear to become extremely scarce in the highlands around the same time that obsidian and pumice temper disappears on the coast suggests the possibility of a relationship between the acquisition and exchange of these items which should be explored further. Volcanic pumice could potentially be identified using Laser Ablation High Resolution Inductively Coupled Plasma Mass Spectrometry as has been done to identify sources of obsidian temper in ceramics (Palumbi et al. 2014). The ability to identify the source of the pumice within this temper may help narrow down a general location from which it was collected and determine if it was the product of distal ashfall along the coast or collected from closer to the original source eruption somewhere within the highlands. If the appearance of pumice within Guangala ceramics on the coast is the product of long-distance exchange, it is unlikely to be from a single eruption. A broad distribution of source ashfalls might suggest that the Guangala were connected to the highlands through a wider system of exchange with numerous trading partners throughout the highlands. Conversely, a few source ashfalls concentrated in a single region or a few closely related regions might suggest the consolidation of exchange amongst a few or even a single group from the highlands. Such an identification could potentially yield clues to broader systems of material distribution and exchange through which obsidian, *Spondylus*, and other materials flowed.

Volcanic ash seems to have been an important component in burial practices for the people of the shaft tomb and burial mound cultures. Whether mixed into the tomb fill, laid on the floor, or used as a stratigraphic marker to determine the depth of the tomb, it appears to have occupied a critical place in the considerations of the builders of shaft tombs. More research on the exact types of volcanic ash used and the volcanic eruptions from which they were produced could yield crucial clues to the relationships between the builders, the volcanos on their landscape, and the eruptions that these volcanos produce. The presence of the intentional volcanic ash layers within the hemispherical burial mounds hint at the phases of construction which were carried out during the creation of the tombs. The fact that there is a break between the phases of construction when the ash layer was laid, and the phase during which the mound was topped off or sealed suggests that this layer may have served as a significant marker for the people constructing the mounds. The composition of this penultimate phase of the mound mirrors the appearance of a volcanic crater alluding to some possible link between the burial mounds and the volcanos. The lack of evidence of wash events during initial mound construction and the consistent construction methods between mounds indicates that these phases were of intentional architectural design and mounds were constructed relatively quickly with little pause between phases. Thus, these constituent phases must have held some symbolic significance to the builders. As the ash layer seems to have been a critical component of the composition of the mound as evidenced by the reconstruction of the ash layer in Mound h after it was reentered, the identification of this volcanic ash and its source eruption could prove useful in drawing connections between these people and the volcanos. More careful stratigraphic analysis of shaft tombs and burial mounds could

dissect these structures in such a way that the relationships between the different constituent sediments, the locations on the landscape from which they were gathered, and the way in which they were incorporated into the tombs can be more fully parsed out.

The Inka appear to have had an extremely practical relationship with volcanic ash for the purpose of construction, opting to use the material as mortar to seal blocks, an aggregate for clay mortar, or to create moisture barriers in ways that seem much more utilitarian than nonutilitarian. The utilitarian use of volcanic ash by the Inka stands in contrast to the Cara who may have been using the ash in a way that is far more indicative of their conceptions of the volcanic landscape, conceptions which the Inka may have only begun to incorporate into their understanding near the end of their occupation. While the use of Inka stonework reflects their conception that stone was living (Dean 2010), there is little volcanic ash around Cusco and their foray into Ecuador may have been their first experience using it widely for construction. The blending of Inka and Cara construction techniques, specifically techniques utilizing volcanic ash, might then yield clues to the integration of the Inka and Cara conceptions of the landscape.

By comparison, the Cara seem to have used volcanic ash for the purpose of construction in a way that may be far more nonutilitarian, perhaps alluding to some symbolic or ritual significance. Though the Cara heavily depended on the use of *cangaua* for the purpose of construction, there is no reason to believe that they would have recognized its volcanic origins as they surely did with volcanic ash. The use of layered dark sediments along with white volcanic pumice within the uppermost portion of the pyramids at Cochasquí seems to have no immediate utilitarian purpose and the sheer quantity of pumice consisting of various grain sizes used for this portion of the

construction implies an intentional effort to seek out and collect the material rather than some accidental inclusion. Though the pyramids at Cochasquí constitute only a small sample of the total number of Cara pyramids in Ecuador, the amount of effort necessitated by their construction and the number of pyramids at the site perhaps represents the pinnacle of Cara religious and social complexity. The fact that the initial construction of the Cara pyramids seems to have been begun shortly after the 1280 AD eruption of Quilotoa directly connects these structures and the complex cultural framework in which they were produced to the volcano and the effect of its eruption.

Perhaps the one aspect of human-volcano interactions made clearer than any other by the cases presented in this thesis, is the relationship between geographic distance and choice of utilitarian and nonutilitarian applications for volcanic ash. The Guangala, located some distance from any active volcanos, seem to have had a largely utilitarian connection with volcanic ash, opting to use the material for the purpose of ceramic production with no apparent nonutilitarian or ritual applications. Though the Guangala may have been distantly affected by volcanic eruptions, there is no reason to believe that such eruptions were a great concern. The Inka, though familiar with the effects of volcanism throughout their empire, appear less focused on utilizing volcanic ash in a nonutilitarian manner though the construction of the temple at San Agustín de Callo and the offering of llamas to Chimborazo described by Paz_Maldonado (1897 [1582]) suggests a recognition of the importance of honoring and appeasing the volcanos. By comparison, the people of the shaft tomb, hemispherical burial mound, and pyramid building cultures of the northern Ecuadorian highlands, who resided amongst the volcanos, look to have gone to great lengths to incorporate volcanic ash into their burial

practices and ritual structures in ways that demonstrate their recognition of the need for the consistent reverence and interconnectedness with these imposing yet life-giving natural features. Despite its ubiquity, there is little indication that the people of the northern highlands chose to use volcanic ash for the purpose of ceramic production or heavily relied on its use as mortar. The choices made by different groups between utilitarian and nonutilitarian aspects of volcanic ash demonstrate the strength of the connection between the people and the volcanic landscape from which it was generated. Those groups more detached from the eruptive source of volcanic ash recognized the usefulness of the material for utilitarian purposes. Those closer to the source appear to have had fewer utilitarian uses for volcanic ash, instead recognizing its more symbolic aspects and choosing to apply the material in ways that strengthened the relationship between the people and these most sacred features of the landscape.

The majority of studies focused on volcanic ash in archaeological contexts still seek to orient our perception of human relationships to volcanic eruptions within the context of the environmental determinism. These studies attempt to understand choice as constrained by the destruction and devastation that drives migration, abandonment, and societal change. Yet the impacts of volcanic eruptions extend far beyond this scope into the realm of opportunity, creation, and human resilience. Human conceptions of volcanos and volcanic eruptions have and always will be dictated by the interplay between the benefits that volcanos can provide and the hinderances generated by their periodic eruptions. The application of landscape theory allows us to explore how human-volcano relationships are experienced through a cultural lens and return a level of agency to the groups we are studying. These relationships are further complicated by the fact that

volcanos were viewed as autonomous features of the landscape and their “actions” as interpreted by the affected populations are more indicative of the cultural interpretations than the physical events. It’s important to remember that although volcanic ash may be immediately representative of a dramatic eruptive event, it may have also been associated with many of the of the more commonplace phenomena related to volcanos such as rain, snow, or hail. Thus, volcanic ash could represent all manner of phenomena connected to volcanos, destructive but also creative. While volcanic ash may have at one time devastated the landscape, it offered a unique material that could be commodified and exchanged, lend its unique physical properties for the purpose of specialized construction, intimately connect groups to some of the most sacred aspects of their landscape, and serve as a catalyst or even a symbol for the religious and social cohesion that, in the case of the Cara, would galvanize a society into a united and formidable opposition against the greatest pre-Columbian empire in the Americas.

REFERENCES CITED

Athens, J. Stephen

- 1980 *El Proceso Evolutivo en Las Sociedades Complejas y la Ocupacion del Periodo Tardio Cara en los Andes septentrionales del Ecuador*. Colección Pendoneros 2, Otavalo.
- 1998 Volcanism and Archeology in the Northern Highlands of Ecuador. In *Actividad Volcánica y Pueblos Precolombinos en el Ecuador*, edited by Patricia Mothes, pp. 111-138. Abya-Yala, Quito.
- 2003 *Inventory of Earthen Mound Sites, Northern Highland Ecuador*. International Archaeological Research Institute, Inc. Report prepared for the H. John Heinz III Grant Program for Latin American Archaeology and the Instituto Nacional de Patrimonio Cultural del Ecuador.
- 2010 El Sitio Tola de la Hacienda Zuleta: Investigaciones geofísicas 2005 y 2009. Submitted to the Instituto Nacional de Patrimonio Cultural. Copies available from the INPC, Quito.

AZO Materials

- 2016 Insulating Castable Refractories: Best Practice for Kiln and Furnace Application. Electronic document, <https://www.azom.com/article.aspx?ArticleID=13310>, accessed May 4, 2018.

Benfer, Robert A, and Andrés Ocás

- 2017 A prehistoric pyramid in the shape of a volcanic cinder cone, Nepeña Valley, Peru. *Antiquity* 357(91):1-6.

Bellot-Gurlet, Ludovic, Olivier Dorighel, and Gérard Poupeau

- 2008 Obsidian provenance studies in Colombia and Ecuador: obsidian sources revisited. *Journal of Archaeological Science* 35:272-289.

Bigazzi, G., M. Coltelli, N.J.C. Hadler, A.M. Osorio Araya, M. Oddone, and E. Salazar

- 1992 Obsidian-bearing lava flows and pre-Columbian artifacts from the Ecuadorian Andes: First new multidisciplinary data. *Journal of South American Earth Sciences* 6(1/2):21-32.

Binford, Lewis

- 1962 Archaeology as Anthropology. *American Antiquity* 28:217-225.

Bordieu, Pierre

- 1989 *Outline of Theory and Practice*. Translated by Richard Nice. Cambridge University Press, Cambridge.

Bouguer, Pierre

- 1749 *La Figure de La Terre: déterminée par les observations de Messieurs Bouguer, & de La Condamine, de l'Académie Royale de Sciences, envoyés par ordre du roy au Pérou, pour observer aux environs de l'Equateur. Avec une relation abrégée de ce voyage, qui contient la description du país dans lequel les opérations ont été faites.* Charles-Antoine Jombert, Paris.

Bray, Tamara L.

- 2008 Late Pre-Hispanic Chiefdoms of Highland Ecuador. In *Handbook of South American Archaeology*, edited by Helaine Silverman and William H. Isbell, pp. 527-544. Springer, New York.

Brown, David O.

- 2000 Informe Preliminar de las Investigaciones Arqueológicas en la Hacienda San Agustín de Callo, Provincia de Cotopaxi Fase III. Submitted to the Instituto Nacional de Patrimonio Cultural. Copies available from the INPC, Quito.
- 2018 Perspectivas sobre los cacicazgos tardíos de la sierra norte del Ecuador. Presented at the IX Reunión de Tería Arqueológica de América del Sur, Ibarra.

Burger, R.L., F. Asaro, H.V. Michel, F.H. Stross, and E. Salazar

- 1994 An initial consideration of obsidian procurement and exchange in prehispanic Ecuador. *Latin American Antiquity* 5:228-255.

Buytaert, W., J. Sevinkc, B. De Leeuw, and J. Deckers

- 2005 Clay mineralogy of the soils in the south Ecuadorian páramo region. *Geoderma* 127:114-129.

Caillavet, Chantal

- 2000 *Etnias del Norte: Etnohistoria e historia de Ecuador.* Abya Yala, Quito.

Camino, Byron and Fausto Sánchez

- 2018 Aproximación a la interpretación de las prácticas funerarias: Transición entre los periodos de Desarrollo Regional a Integración, Urcuquí, Provincia de Imbabura, Ecuador. Presented at the IX Reunión de Tería Arqueológica de América del Sur, Ibarra.

Chung, Heajoo and Youngsun Song

- 2014 The Meaning of Volcanic Ash Characteristics Found in the Archaeological Pottery of Chichen Itza, Yucatan, Mexico. *Mediterranean Archaeology and Archaeometry* 14(2):155-167.

- Coffey, Kevin T. Axel K. Schmitt, Anabel Ford, Frank J. Spera, Constance Christensen, and Jennifer Garrison
- 2014 Volcanic ash provenance from zircon dust with an application to Maya pottery. *Geology* 42(7):561-640.
- Cordero, María Auxiliadora
- 2009 *El cacicazgo Cayambi: Trayectoria hacia la complejidad social en los Andes septentrionales*. Abya-Yala, Quito.
- Dean, Carolyn
- 2010 *A Culture of Stone*. Duke University Press, Durham and London.
- Delvaux, B., A.J. Herbillon, L. VielVoye, and M.M. Mestdagh
- 1990 Surface Properties and Clay Mineralogy of Hydrated Hallositic Soil Clays. II: Evidence for the Presence of Halloysite/Smectite (H/Sm) Mixed-Layer Clays. *Clay Minerals* 25:141-160.
- De Sutter, Patrick
- 1984 Técnicas Tradicionales en Tierra en la Construcción de Vivienda en el Área Andina del Ecuador. *Ecuador Debate: campesinado y tecnología* 6:106-113.
- 1986 “*Hagamos Nuestra Casa*”. Instituto Nacional de Patrimonio Cultural, Quito.
- Doyon, Leon G.
- 1988 Tumbas de la nobleza en La Florida. In *Quito Antes de Benalcazar*, edited by I. Cruz Cevallos, pp. 51-66, 86-100, Quito. Centro Cultural Artes.
- 1991 The Pit and the Pyramid: Social Hierarchy, Historical Contingency, and Thermodynamics in the Development of Monumentalism in the Northern Highlands of Ecuador. Presented at the 56th Annual Meeting of the Society for American Archaeology, New Orleans.
- 2002 Conduits of Ancestry: Interpretation of the Geography, Geology, and Seasonality of North Andean Shaft Tombs. *Archaeological Papers of the American Anthropological Association* 11(1):79-95.
- Dyrdahl, Eric, Carlos Eduardo Montalvo Puente, and Viviana Valverde Arco
- 2017 Una historia complicada: Ceniza volcánica y su uso en el período Formativo Tardío en la Sierra Norte del Ecuador a través del caso del sitio «Los Soles» (sector Las Orquídeas) In *Volcanes, cenizas y ocupaciones antiguas en perspectiva geoarqueología en América Latina*, edited by María Fernanda Ugalde, pp. 87-101. Pontificia Universidad Católica del Ecuador, Quito.

Echeverría Almeida, José

- 2004 *Las Sociedades Prehispánicas de la Sierra Norte del Ecuador: Una aproximación arqueológica y antropológica*. Perspectiva Histórica Vol. 1(1). Imprenta Noción, Quito.

Espinosa, José, Julio Moreno, and Gustavo Bernal (editors)

- 2018 *The Soils of Ecuador (World Soils Book Series)*. Springer International, Cham, Switzerland.

European Coatings

- 1999 Insulating with Volcanic Ash. Electronic document, <http://www.european-coatings.com/Editorial-archive/Insulating-with-volcanic-ash>, accessed May 4, 2018.

Ezziane, K., A Bougara, A Kadri, H Khelafi, and E. Kadri

- 2007 Compressive strength of mortar containing natural pozzolan under various curing temperature. *Cement and Concrete Composites* 29:587-593.

Faieta-Boada, S.M. and I.J. McColm

- 1993 Preliminary analysis of the thermal behaviour of an industrially used Ecuadorian clay. *Applied Clay Science* 8(2-3):215-230.

Figueroa Arciniega, Silvia Pilar

- 2015 Evidencia de complejidad social al final del Período Formativo Tardío, bajo de la ceniza del volcán Pululahua (2400 a A.P.). Master's thesis, Department of Anthropology, Universidad Católica, Quito.

Ford, A., and H. Glicken

- 1987 The Significance of Volcanic Ash Tempering in the Ceramics of the central Maya Lowlands. In *Maya Ceramics*, edited by P.M. Rice and R.J. Sharer, pp. 479-502. Oxford.

Ford, Anabel, and William Rose

- 1995 Volcanic Ash in Ancient Maya Ceramics of the Limestone Lowlands: Impacts of Prehistoric Volcanic Activities in the Guatamala Highlands. *Journal of Volcanology and Geothermal Research* 66:149-162.

Francou, B.

- 1990 Stratification mechanisms in slope deposits in high sub-equatorial mountains. *Permafrost Periglacial Processes* 1:249-263.

Fries, Eric C.

- 2010 Maize at Molino Loma: Imperial Inka Infrastructure on the Northern Ecuadorian Frontier. Master's Thesis submitted to the University of California Los Angeles, California.

Gaydarska, B., J. C. Chapman, I. Angelova, M. Gurova and S. Yanev

- 2004 Breaking, making and trading: the Omurtag Eneolithic Spondylus hoard. *Archaeologia Bulgarica* 8(2):11-33.

Gnecco, Cristobal

- 1994 The Pleistocene/*Holocene* Boundary in the Northern Andes: An Archaeological Perspective. PhD dissertation, Department of Anthropology, Washington University, St. Louis.

Gobierno de Provincia de Pichincha

- 2001 Informe proyecto rescate y monitoreo canal de riego Tabacundo. Parque arqueológico y de investigación científica Cochasquí.

Greider, Thomas and Lorraine Garkovitch

- 1994 Landscapes: The Social Construct of Nature and the Environment. *Rural Sociology* 59(1):1-24.

Guarino, FM., F. Angelini, C. Vollono, and C. Orefice

- 2006 Bone preservation in human remains from the Terme del Sarno at Pompeii using light microscopy and scanning electron microscope. *Journal of Archaeological Science* 33:513-520.

Gudmundsson, Gunnar

- 2011 Respiratory health effects of volcanic ash with special reference to Iceland. A review. *The Clinical Respiratory Journal* 5:2-9.

Guffroy, Jean

- 2008 Cultural Boundaries and Crossings: Ecuador and Peru. In *Handbook of South American Archaeology*, edited by Helaine Silverman and William H. Isbell, Pp. 889-902. Springer, New York.

Guignabaudet, Philippe

- 1953 Nuevos descubrimientos arqueológicos en las Tolas de Huaraquí. Boletín de Informaciones Científicas Nacionales 6(56):168-186.

Hall, Minard L.

- 1977 *El volcanismo en el Ecuador*. Instituto Panamericano de Geografía e Historia, Quito.

Hall, Minard L. and Patricia A. Mothes

- 1994 Tefrostratigrafía holicénica de los volcanes principales del Valle Interandino, Ecuador. In *Estudios de Geografía* Vol. 6, edited by R. Morocco, pp. 47-67. Colegio de Geógrafos del Ecuador, Quito.
- 1997 El origen y la edad de la cangahua superior, valle de Tumbaco (Ecuador). Presented at the Memorias del III simposio Internacional Sobre Suelos volcánicos endurecidos, Quito.
- 1998 La Actividad Volcánica del Holoceno en el Ecuador y Colombia Austral: Impedimento al desarrollo de las civilizaciones pasadas. In *Actividad Volcánica y Pueblos Precolombinos en el Ecuador*, edited by Patricia Mothes, pp. 11-40. Abya-Yala, Quito.
- 2008 Ecuador: An overview of young dactic volcanism in a lake-filled caldera. *Journal of Volcanology and Geothermal Research* 176:44-55.

Harichane, Khelifa, Mohammed Ghrici, and Said Kenai

- 2012 Effect of the combination of lime and natural pozzolana on the compaction and strength of soft clayey soils: a preliminary study. *Environmental Earth Science* 66:2197-2205.

Hechler, Ryan S.

- 2014 Alternative Inka Imperial Strategies in Northern Ecuador: A Comparative Study of Tawantinsuyu's Subjugation of the Caranqui Confederation and the Yumbos. Master's thesis, Department of Anthropology, McGill University, Montreal.

Heine, Klaus

- 2011 Late Quaternary Glaciations of Ecuador. *Developments in Quaternary Science* 15:803-812.

Herrera y Tordesillas, Antonio de

- 1726 [1625] *Historia General de los Hechos de los Castellanos en las Islas y Tierra Firme del Mar Oceano*. La Imprenta Real de Nicolas Rodriguez Franco, Madrid.

Horwell, Claire J. and Peter J. Baxter

- 2006 The respiratory health hazards of volcanic ash: a review for volcanic risk mitigation. *Bulletin of Volcanology* 69(1):1-24.

Humboldt, Alexander von

- 1810 *Vues des Cordillères et monuments des peuples indigènes de l'Amérique*. Chez N. Maze, Libraire, Rue Gît-le-Coeur, No. 4, Paris.
- 1850 *Views of Nature: or Contemplations on the Sublime Phenomena of Creation*. Translated by E.C. Otté and Henry G. Bohn. Henry G. Bohn, London.

- 1864 *Volcans des Cordillères de Quito et du Mexique, pour servir aux œuvres de Humboldt et spécialement aux mélanges de géologie et de physique générale.* Librairie des Sciences Naturelles et des Artes Illustrés, Paris.
- 1883 [1862] *Cosmos: A Sketch of a Physical Description of the Universe Vol. V.* Translated by E.C. Otté and W.S. Dallas. George Bell and Sons, London.
- 1905 [1802] Au même [A. Wilhelm de Humboldt], a Lima, ce 25 novembre 1802. In *Lettres américaines d'Alexandre de Humboldt (1798-1807)*. Ernest-Théodor Hamy, ed. Pp. 127-139. E. Guilmoto, Paris.
- Isaacson, John S.
- 1987 *Volcanic Activity and Human Occupation of the Northern Andes: The Application of Tephrostratigraphic Techniques to the Problem of Human Settlement in the Western Montaña during the Ecuadorian Formative.* Ph.D. Dissertation, University of Illinois, Urbana-Champaign.
- Isaacson, John S. and James A. Zeidler
- 1998 *Accidental History: Volcanic Activity and the End of the Formative in Northwestern Ecuador.* In *Actividad Volcánica y Pueblos Precolombinos en el Ecuador*, edited by Patricia Mothes, pp. 41-72. Abya-Yala, Quito.
- Jackson, Marie, Daniel Deocampo, Fabrizio Marra, and Barry Scheetz
- 2010 *Mid-Pleistocene Pozzolan Volcanic Ash in Ancient Roman Concretes.* *Geoarchaeology: An International Journal* 25(1):36-74.
- Jijón y Caamaño, J.
- 1914 *Contribución al Conocimiento de los Aborígenes de la Provincia de Imbabura.* Blas y Cia, Madrid.
- 1920 *Nueva Contribución al Conocimiento de los Aborígenes de la Provincia de Imbabura.* *Boletín de la Sociedad Ecuatoriana de Estudios Históricos Americanos* 4(10): 1-120.
- Jordan, M.M., F. Pardo, and T. Sanfeliu
- 2014 *Ceramic Behaviour of Some Raw Materials from Ecuador.* *Intercam: International Ceramic Review* 1(2):36-38.
- Joussein, E., S. Petit, J. Churchman, B. Theng, D. Righi, and B. Delvaux
- 2005 *Hallosite Clay Minerals – a review.* *Clay Minerals* 40:383-426.
- Juan, Jorge and Antonio de Ulloa
- 1748 *Relacion Historica del Viage a la America Meridional Hecho de Orden de S. Mag. para Medir Algunos Grados de Meridiano Terrestre, y venir por ellos en conocimiento de la verdadera Figura y Magnitud de la Tierra, con otras varias Observaciones Astronomicas, y Phisicas: Primera Parte.* Antonio Marin, Madrid.

Kansas Geological Survey

- 2005 Uses of Volcanic Ash—Present and Potential. Electronic document, http://www.kgs.ku.edu/Publications/Bulletins/96/06_uses.html, accessed May 4, 2018.

Knapp, Gregory

- 1988 *Ecología Cultural Prehispánica del Ecuador*. Banco Central del Ecuador, Quito.

Knapp, Gregory and Patricia A. Mothes

- 1998 Quilotoa Ash and Human Settlements in the Equatorial Andes. In *Actividad Volcánica y Pueblos Precolombinos en el Ecuador*, edited by Patricia Mothes, pp. 149-156. Abya-Yala, Quito.

Lavigne, Franck, Jean-Philippe Degeai, Jean-Christophe Komorowski, Sébastien Guillet, Vincent Robert, Pierre Lahitte, Clive Oppenheimer, Markus Stoffel, Céline M. Vidal, Surono, Indyo Pratomo, Patrick Wassmer, Irka Hajdas, Danang Sri Hadkomo, and Edouard de Belizal

- 2013 Source of the great A.D. 1257 mystery eruption unveiled, Samalas volcano, Rinjani Volcanic Complex, Indonesia. *PNAS* 110(42):16742-16747.

Ledru, M.P., V. Jomelli, Pablo Samaniego, Mathias Vuille, S. Hidalgo, M. Herrera, and C. Ceron

- 2013 The Medieval Climate Anomaly and the Little Ice Age in the eastern Ecuadorian Andes. *Climate of the Past* 9:301-321.

Leon, Cieza de

- 1989 [1553] *Crónica del Perú Tercera Parte*. Pontificia Universidad Católica del Perú, Lima.

Lippi, Ronald D.

- 2003 Formative Period Chronology for the Northern and Central Highlands of Ecuador. In *Archaeology of Formative Ecuador*. J. Scott Raymond and Richard L. Burger, eds. Pp. 529-537. *Dumbarton Oaks Research Library and Collection*, Washington, D.C.

Los Cabildos de Quito (LCQ)

- 1934 [1534-1543] *Libro primero de cabildos de Quito, Vol. 2.*, edited by Jozé Rumazo González. *Archivo Municipal de Quito*, Quito.

Maldonado, Paz

- 1897 [1582] *Relacion del pueblo de Sant-Andres Xunxi para el muy ilustre señor licenciado Francisco de Auncibay del concejo de su majestad y su oydor el la real audiencia de Quito*. In *Relaciones Geográficas de Indias*, Vol. 3, pp 149-154. *Tipographia de los hijos de M.G. Hernández*, Madrid.

Manaresi, R. Rossi and R. Pellizzer

- 1979 The Volcanic Tuff of the Archaeological Monuments at Cochasquí, Ecuador: Cause of Decay and Effectiveness of Conservation Treatments. Presented at the 3rd International Congress on Deterioration and Preservation of Stones, Venezia.

Mastrolorenzo, Giuseppe, Pierpaolo Petrone, Lucia Pappalardo, and Fabio M. Guarino

- 2010 Lethal Thermal Impacts at Periphery of Pyroclastic Surges: Evidences at Pompeii. *PLoS ONE* 5(6):e11127.

Masucci, Maria A.

- 2000 Defining Ceramic Change and Cultural Interaction: Results of Typological, Chronological, and Technological Analysis of Guangala Phase Ceramics. *Andean Past* 6(10)175-208.
- 2008 Early Regional Polities of Coastal Ecuador. Helaine Silverman and William H. Isbell, eds. Pp. 489-503. Springer, New York.

Masucci, Maria A. and Allison Macfarlane

- 1997 An Application of Geological Survey and Ceramic Petrology to Provenance Studies of Guangala Phase Ceramics of Ancient Ecuador. *Geoarchaeology* 12(7)765-793.

Mayer-Oakes, William J.

- 1963 Early Man in the Andes. *Scientific American* 208(5):116-129.

McNutt, Stephen and Earle R. Williams

- 2010 Volcanic lightning: global observations and constraints on source mechanisms. *Bulletin of Volcanology* 72:1153-1167.

Meyers, Albert

- 1976 *Die Inka in Ekuador: Untersuchungen anhand ihrer materiellen Hinterlassenschaft*. Bonner Amerikanistische Studien 6, Bonn.

Miller, Gifford H., Áaslaug Geirsdóttir, Yafang Zhong, Darren J. Larsen, Bette L. Otto-Bliesner, Marika M. Holland, David A. Bailey, Kurt A. Refsnider, Scott J. Lehman, John R. Southon, Chance Anderson, Helgi Björnsson, and Thorvaldur Thordarson.

- 2012 Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks. *Geophysical Research Letters* 39:L02708.

Minc, Leah, Kaitlin Yanchar, Tamara Bray, and José Echeverría

- 2016 Potting Clays and Ceramic Provenance in Northern Highland Ecuador. In *Vessels Explored: Applying Archaeometry to South American Ceramics and their Production* edited by Emily Stovel and Gustavo de la Fuente, pp. 47-63. British Archaeological Reports International, Oxford.

Mok, Kimberly

- 2016 Small House in Ecuador is Insulated with Pumice Stone. Electronic document, <https://www.treehugger.com/tiny-houses/ecuador-small-house-insulated-pumice-stone-luis-velasco-roldan-angel-hevia-antuna.html>, accessed March 23, 2018.

Mothes, Patricia A. and Minard L. Hall

- 1991 Mapa de los peligros volcánicos asociados con el Volcán Quilotoa, Provincia de Cotopaxi. Instituto Geofísico, Escuela Politécnica Nacional, Quito.
- 1997 Quilotoa Caldera, Ecuador: a young eruptive center in the Western Cordillera. *IAVCEI General Assembly Proceedings*, Mexico, p. 49.
- 1998 Quilotoa's 800 y BP Ash: A valuable stratigraphic marker unit for the integration period. In *Actividad Volcánica y Pueblos Precolombinos en el Ecuador*, edited by Patricia Mothes, pp. 111-138. Abya-Yala, Quito.
- 2008 The Plinian fallout associated with Quilotoa's 800 yr BP eruption, Ecuadorian Andes. *Journal of Volcanology and Geothermal Research* 176:56-69.

Di Muro, A., M. Rosi, E. Aguilera, R. Barbieri, G. Massa, F. Mundula, and F. Pieri

- 2008 Transport and sedimentation dynamics of transitional explosive eruption columns: The example of the 800 BP Quilotoa Plinian eruption (Ecuador). *Journal of Volcanology and Geothermal Research* 174(307-324).

Narr, Karl J. and Uwe Schönfelder

- 1989 Fechas de Carbon 14. In *Excavaciones en Cochasquí, Ecuador 1964-1965*, edited by U. Oberem, pp. 177-179. Mainz am Rhein: Verlag Philipp Von Zabern.

Newhall, Christopher G. and Stephen Self

- 1982 The Volcanic Explosivity Index (VEI): An Estimate of Explosive Magnitude for Historical Volcanism. *Journal of Geophysical Research* 87(C2):1231-1238.

Oberem, U. and R. Hartmann

- 1981 Informe de Trabajo Sobre las Excavaciones Arqueológicas de 1964-1965. In *Cochasquí: Estudios Arqueológicos*, edited by U. Oberem, pp. 39-57. Colección Pendoneros, vol. 3. Instituto Otavaleño de Antropología, Otavalo.

Oberem, Udo, and Wolfgang Wurster

- 1989 *Excavaciones en Cochasquí, Ecuador 1964-1965*, edited by U. Oberem. Mainz am Rhein: Verlag Philipp Von Zabern.

Ogburn, Dennis E.

- 2012 Reconceiving the Chronology of Inca Imperial Expansion. *Radiocarbon* 54(2):219-237.

O'Rourke, T.D. and E. Crespo

- 1988 Geotechnical Properties of Cemented Volcanic Soil. *Journal of Geotechnical Engineering* 114(10):1126-1147.

Ortiz Arciniegas, Lenin

- 2009 *Cochasqui: el agua del frente de la mitad*. Letras, Quito.

Palumbi, Giulio, Bernard Gratuze, Armine Harutyunyan, and Christine Chataigner

- 2014 Obsidian-tempered pottery in the Southern Caucasus: a new approach to obsidian as a ceramic-temper. *Journal of Archaeological Science* 44:43-54.

Paulsen, Allison C.

- 1974 The Thorny Oyster and the Voice of God: Spondylus and Strombus in Andean Prehistory. *American Antiquity* 39(4):596-607.

Pearson, Georges A.

- 2017 Bridging the Gap: An Updated Overview of Clovis across Middle America and its Techno-Cultural Relation with Fluted Point Assemblages from South America. *PaleoAmerica* 3(3):203-230.

Perlite Institute

- 2013 Perlite as High Temperature Insulation. Electronic document, <https://www.perlite.org/library-perlite-info/industrial-perlite/Perlite-HighTempApplications.pdf>, accessed May 4, 2018.

Porras, P.I.

- 1980 *Arqueología del Ecuador*. Editorial Gallocapitan, Otavalo.

Pratt, William S., David O. Brown, Dana Anthony, Patricia Mothes

- 2015 The Sieve and the Sand: Inka Foundations in the North of the Empire. Presented at the 80th Annual Meeting of the Society for American Archaeology, San Francisco.

Protzen, Jean-Pierre

- 1983 Inka Quarrying and Stonecutting. *Ñawpa Pacha: Journal of Andean Archaeology* 21:183-214.

Quantin, Paul and Claude Zebrowski

- 1997 Caractérisation et formation de la *cangahua* en Équateur: Analyse préliminaire (chimie, minéralogie, pétrographie) de quelques types de *canhahua*. Presented at the Memorias del III simposio Internacional Sobre Suelos volcánicos endurecidos, Quito.

Raymond, J. Scott

- 2003 Social Formations in the Western Lowlands of Ecuador During the Early Formative Period. In *Archaeology of Formative Ecuador*, edited by J. Scott Raymond, Richard L. Burger, and Jeffrey Quilter, pp. 33-67. Dumbarton Oaks Research Library and Collection, Washington, D.C.

Rice, Prudence M.

- 2015 *Pottery Analysis: A Sourcebook*. University of Chicago Press, Chicago and London.

Riedinger, Melanie Ann

- 1993 The Application of Fossil Diatom Assemblages in Reconstructing Mid to Late Holocene Climate in the Neotropics: The Paleolimnology of Huarmicocha and Lake Ayauchi, Ecuador. PhD dissertation, Department of Zoology, Ohio State University, Columbus. University Microfilms, Ann Arbor.

Rowe, John Howland

- 1945 Absolute Chronology in the Andean Past. *American Antiquity* 10(3):265-284.

Sackett, James R.

- 1982 Approaches to Style in Lithic Archaeology. *Journal of Anthropological Archaeology* 1:59-112.
- 1989 Style and ethnicity in archaeology: the case for isochestism. In *The Uses of style in archaeology*, edited by Christine Hastorf, Ann Conkey, and Margaret Wright, pp. 32-43. Cambridge University Press, Cambridge.

Salomon, Frank

- 1987 *Native Lords of Quito in the Age of the Incas: The Political Economy of North Andean Chiefdoms*. Cambridge University Press, Cambridge.

Sarmiento de Gamboa, Pedro

- 1907 [1572] *History of the Incas*. Translated by Sir Clements Markham. Cambridge.

Sauer, Carl

- 1925 The morphology of landscapes. *University of California Publications in Geography* 2:19-54.

Schick, R.

- 1981 Source Mechanisms of Volcanic Earthquakes. *Bulletin of Volcanology* 44(3):491-497.

Senhadji, Y., G Escadeillas, M Mouli, H. Khelaji, and Benosman

- 2014 Influences of natural pozzolan, silica fume and limestone fine on strength, acid resistance and microstructure of mortar. *Powder Technology* 254:314-323.

Serra, M.F., M.S. Conconi, G. Suarez, E.F. Aglietti, and N.M. Rendtorff

- 2015 Volcanic Ash as Flux in Clay Based Triaxial Ceramic Materials, Effect of the Firing Temperature in Phases and Mechanical Properties.

Sherwood, Sarah C. and Tristram R Kidder

- 2011 The DaVincis of dirt: Geoarchaeological perspectives on Native American mound building in the Mississippi River basin. *Journal of Anthropological Archaeology* 30:69-87.

Shoji, S., M. Nanzyo, and R. Dahlgren

- 1994 Volcanic Ash Soils: Genesis, Properties, and Utilization. *Developments in Soil Science* Vol. 21. Elsevier Science. *Ceramics International* 41:6169-6177.

Slawinska, Joanna and Alan Robock

- 2018 Impact of Volcanic Eruptions on Decadal to Centennial Fluctuations of Arctic Sea Ice Extent during the Last Millennium and on Initiation of the Little Ice Age. *American Meteorological Society* 31:2145-2167.

Stahl, Peter W.

- 2003 The zooarchaeological record from Formative Ecuador. In *Archaeology of Formative Ecuador*, edited by J. Scott Raymond and Richard L. Burger, pp. 175–212. Dumbarton Oaks, Washington, D.C.

Stohtert, Karyn E.

- 1985 The Preceramic Las Vegas Culture of Coastal Ecuador. *American Antiquity* 50(3):613-637.
- 1988 La Prehistoria Temprana de la Península de Santa Elena, Ecuador: Cultura Las Vegas. *Miscelánea Antropológica Ecuatoriana Series 10*. Museos de Banco Central del Ecuador, Guayaquil.

Toulkeridis, Theofilos

- 2016 Chalupas: Un Super-Volcan Ecuatoriano que Amenaza a Todo el Planeta. *Revista de Ciencias de Seguridad y Defensa* 1(2):1-8.

Ubelaker, Douglas H.

- 2000 Human Remains from La Florida, Quito, Ecuador. *Smithsonian Contributions to Anthropology* 43

Ugalde, María Fernanda

- 2017 La cangahua: un depósito pleistocénico con funciones constructivas y de marcador cronológico para la arqueología ecuatoriana. In *Volcanes, cenizas y ocupaciones antiguas en perspectiva geoarqueología en América Latina*, edited by María Fernanda Ugalde, pp. 87-101. Pontificia Universidad Católica del Ecuador, Quito.

Uhle, Max

- 1933 Die Ruinen von Cochasquí. *Ibero-Amerikanisches Archiv* 7(2):127-134.

Valdez, Francisco

- 2008 Inter-zonal Relationships in Ecuador. In *Handbook of South American Archaeology*, edited by Helaine Silverman and William H. Isbell, Pp. 865-888. Springer, New York.

Velasco, Juan de

- 1841 [1789] *Historia del reino de Quito en la América meridional*. Imprenta de Gobierno, por Juan Campuzano, Quito

Volentik, Alain C.M., Costanza Bonadonna, Charles B. Connor, Laura J. Connor, and Mauro Rosi

- 2010 Modeling tephra dispersal in absence of wind: Insights from the climatic phase of the 2450 BP Plinian eruption of Pululagua volcano (Ecuador). *Journal of Volcanology and Geothermal Research* 193(117-136).

Wagner, G.

- 1978 Archaeological applications of fission-track dating. *Nuclear Track Detection* 2:51-64.

Wentscher, Jürgen

- 1989 Montículos y otras áreas de investigación. In *Excavaciones en Cochasquí, Ecuador 1964-1965*, edited by U. Oberem, pp. 70-103. Mainz am Rhein: Verlag Philipp Von Zabern.

Whymper, Edward

- 1892 *Travels Amongst the Great Andes of the Equator*. John Murray, Albemarle Street, London.

Wilson, Clare, Ian A. Simpson, and Elizabeth J. Currie

- 2002 Soil Management in Pre-Hispanic Raised Field Systems: Micromorphological Evidence from Hacienda Zuleta, Ecuador. *Geoarchaeology: An International Journal* 17(3):261-283.

Wurster, Wolfgang

- 1989 Pirámides. In *Excavaciones en Cochasquí, Ecuador 1964-1965*, edited by U. Oberem, pp. 19-65. Mainz am Rhein: Verlag Philipp Von Zabern.

Zalles-Flossbach, Carlos

- 1989 Análisis de los artefactos líticos. In *Excavaciones en Cochasquí, Ecuador 1964-1965*, edited by U. Oberem, pp. 218-229. Mainz am Rhein: Verlag Philipp Von Zabern.

Zebrowski, Claude and Azucena Vicuña

- 1997 El cultivo de la cangahua en el medio campesino tradicional en el Ecuador. Presented at the Memorias del III simposio Internacional Sobre Suelos volcánicos endurecidos, Quito.

Zehetner, F., W.P. Miller, and L.T. West

- 2003 Pedogenesis of Volcanic Ash Soils in Andean Ecuador. *Soil Science Society of America Journal* 67:1797-1809.

Zeidler, James A.

- 1995 Archaeological survey and site discovery. In *Archaeology in the lowland American tropics*, edited by Peter W. Stahl, pp. 7-41. Cambridge University Press, Cambridge.
- 2003 Formative Period Chronology for the Coast and Western Lowlands of Ecuador. In *Archaeology of Formative Ecuador*, edited by J. Scott Raymond and Richard L. Burger, pp. 487-527. Dumbarton Oaks Research Library and Collection, Washington, D.C.
- 2008 The Ecuadorian Formative. In *Handbook of South American Archaeology*, edited by Helaine Silverman and William H. Isbell, pp. 459-488. Springer, New York.

Zhong, Y., G.H. Miller, B.L. Otto-Bliesner, M.M. Holland, D.A. Bailey, D.P. Schneider, and A. Geirsdottir

- 2010 Centennial-scale climate change from decadal-paced explosive volcanism: a coupled sea ice-ocean mechanism. *Climate Dynamics* 37:2373-2387.