THE APPLICATION OF PHYTOLITH AND STARCH GRAIN ANALYSIS TO UNDERSTANDING FORMATIVE PERIOD SUBSISTENCE, RITUAL, AND TRADE ON THE TARACO PENINSULA, HIGHLAND BOLIVIA

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By

AMANDA LEE LOGAN

Supervisor: Dr. Deborah M. Pearsall

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Dedicated to the memory of my grandmother

Joanne Marie Higgins

1940-2005

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ABSTRACT

During the Formative period in the Lake Titicaca basin, a number of social and economic processes develop that form the later foundations of the Tiwanaku state. This thesis employs microfossil data to add to our understanding of three factors viewed as critical in the development of Tiwanaku. Changes in agricultural or subsistence practice are documented by looking at local plants and Andean tubers. Ritual and trade activities are addressed by tracking hallucinogenic and exotic plants. Finally, the role of maize as a potential trade item is evaluated.

This study reports on phytolith and starch grain analysis of Formative period subsistence, trade, and ritual activities as part of the larger Taraco Archaeological Project (TAP). Comparative plant, archaeological soil, and archaeological artifact residue samples were analyzed in order to address the role of local subsistence plants, hallucinogenic and exotic species, and maize at four sites (Chiripa, Kala Uyni, Sonaje, and Kumi Kipa) located on the Taraco Peninsula in the Lake Titicaca basin (Bolivia).

Evidence for Andean tubers was limited, and most local subsistence plants did not produce diagnostic phytoliths. Several diagnostics were discovered for major South American hallucinogens, but none were discovered in archaeological samples. Exotic plant indicators are present in TAP samples, although the signature is weak. Finally, due to overlap of maize inflorescence diagnostics with local wild festucoid grass phytoliths, alternate methods of identifying maize were explored and developed. Maize was discovered in several artifact residues and soil samples, providing some of the earliest evidence for this crop in this region. These results contribute significantly to discussions of the potential for future microfossil work in the highland Andes.

CHAPTER 1
INTRODUCTION

The Andean highlands of South America are home to unique agricultural technologies and adaptations, including the potato and a host of other crops that form an important part of traditional subsistence well into modern times. The region straddles the rich Amazonian rainforest to the east, and the arid Peruvian coastal desert to the west, and has engaged in a diverse array of relationships with both the people and the environments of these locales. It is in this cultural and technological milieu that the complex socioeconomic and belief systems of Andean peoples develop.

Despite the archaeological attention devoted to South America and the Andes in general, few studies document the role of various subsistence, trade, and ritual plants in the development of these systems. Several factors have contributed to this discrepancy. First is a problem of sampling—many of the archaeological sites excavated in the Andes before c. 1970 did not employ systematic botanical sampling and flotation. The second problem is one of happenstance—many of the plants of interest, particular tubers and hallucinogens, rarely preserve as charred macroremains, due to the soft nature of many of the tissues, or a lack of exposure to fire. Finally, many of the specialized archaeobotanical techniques now available, such as starch grain analysis, were not sufficiently well developed and accepted in archaeology until recently.

This thesis employs phytolith and starch grain analysis to address the role of subsistence, trade, and ritual plants during the Formative period of highland Bolivia. As part of the larger Taraco Archaeological Project, it seeks to examine these plants within a context of the development of multi-community polities in the region, eventually

culminating in the rise of the Tiwanaku state. As one of the few examples of the application of microfossil analysis to the highland Andes, this study in large part is devoted to addressing issues concerning methodology and approach, and evaluating the potential of phytolith and starch grain analysis in the region.

The aims of this research are to delimit phytolith production and potential diagnostics in plants of interest, identify methodological problems and possible solutions to the application of phytolith and starch grain analysis in the Andes, and use these techniques to address ritual, trade, and subsistence during the Formative period. Four research questions frame this study:

1. What is the potential for using calcium oxalate crystals to identify plants archaeologically? (Chapter 3)

2. Can subsistence crops, including the native Andean tubers and quinoa, be identified using microfossil analysis, and if so, what is the role of these plants during the Formative period? (Chapter 4)

3. Using phytolith analysis, is it possible to identify and track hallucinogens? Are other exotic plants present during this time? (Chapter 5)

4. What is the role of maize on the Taraco Peninsula during the Formative period? (Chapter 6)

In the chapters to follow, the archaeological background to the Formative period of highland Bolivia and the subsequent development of Tiwanaku will be explained. The archaeobotanical issues that arise out of these research questions will be outlined. The basic methods used in this study will be presented in Chapter 3, but specific methodological issues that arise as part of the main research questions are addressed in their respective chapters. One chapter is devoted to each research question, providing the necessary background, methods, and results for a clear understanding of the issues presented and questions raised. Finally, based on the evidence presented in this thesis, the

discussion considers the role of subsistence, trade, and ritual plants in the Formative period, as well as the potential for microfossil research in the Andes.

CHAPTER 2
ARCHAEOLOGICAL BACKGROUND

INTRODUCTION

The Andean highlands are home to a rich and varied past. Cultural hallmarks include the development of specialized agricultural technologies and adaptations for highland cultivation, unique social structures that involved complex ritual life, and extensive trade systems that served to connect the highlands to the tropical lowlands and coastal deserts. These features played a major role in the development of the first pristine state in the Titicaca region, Tiwanaku. It is unclear, however, how and when these complexities came into being, and what role they played in the emergence of state-level society.

This chapter examines the development of Tiwanaku through its antecedents during the Formative period in the Lake Titicaca basin. First, the main features of Tiwanaku are outlined, followed by three models that attempt to explain the development of the state. Archaeology of the Formative period in highland Bolivia is discussed in reference to these three models. The relevance of archaeobotanical data, particularly microfossil analysis, to evaluating each hypothesis is highlighted.

TIWANAKU

Around AD 400, social organization in the southeastern Lake Titicaca basin shifts from complex chiefdoms to that of an archaic state. Stanish (2003) characterizes this shift as that of local or regional social organization, to that of an expansive society, including control over a larger territory over a number of formerly divided political and/or ethnic factions. The degree of state control over various portions of the empire depends on the

strength of political alliances and geographic distance from the "core" (Stanish 2003:169-171). At its height, Tiwanaku's authority extended from the highlands west to Arica (Chile), Moquegua (Peru), and the Majes drainage (Peru) (Stanish 2003: 171-2).

Centered at Tiwanaku, a large urban settlement in the southeast corner of Lake Titicaca, the Tiwanaku state reigned from approximately AD 400-1100 (Kolata 1993, 1996, 2003; Ortloff and Kolata 1993). The combination of a heavily populated urbanized capital city, a large agricultural base, establishment of road networks and colonies, all suggest that Tiwanaku was the first state in the Titicaca basin. The architectural core at Tiwanaku includes a large stone faced pyramid (the Akapana) with a sunken court at the top, an adjacent large walled enclosure called the Kalasasaya, surrounding another sunken court, and a short distance away, the Pumapunku, a mound with elaborate stone and adobe architecture and a series of subterranean canals (Kolata 2003a,b; Stanish 2003).

The economic system of Tiwanaku centered around raised field and rain fed agriculture, exploitation of lacustrine resources, raising camelids, production of obsidian and metal tools as well as art objects (Kolata 1993, 1996, 2003a; Stanish 2003). Tiwanaku actively imported obsidian, copper, sodalite, and probably maize (Stanish 2003). Archaeobotanical remains suggest that *Chenopodium* (*i.e.* quinoa and kaniwa) formed the majority of the diet, followed by potatoes, other tubers, and imported maize (Hastorf *et al.* 2006; Wright *et al.* 2003). As well, hallucinogen paraphenilia has also been associated with Tiwanaku (Stanish 2003; Torres 1995; Wassen 1972).

MODELS OF THE DEVELOPMENT OF TIWANAKU

Three models have been proposed to explain the emergence of the Tiwanaku state. Before considering these models, definitions of state level organization are first reviewed.

The three main models for the rise of Tiwanaku, corresponding archaeological predictions and possible microfossil signatures for each are outlined.

Defining the State

Before discussing models of the emergence of Tiwanaku, it is important to consider the defining characteristics of a state level society, along with the respective archaeological manifestations. Definitions of state vary considerably, however most agree that social stratification and the appearance of an elite class are key elements. Elite help manage the organization of labor for large state sponsored projects, such as landscape modification and monumental architecture. The elite class of a state society is non-kin based, as opposed to kin based chiefdom societies (Stanish 2001). Craft specialization is also cited as a feature of statehood (Janusek 1999; Stanish 2001). Isbell and Schrieber (1978) use a broader definition that takes into account the relative frequency of decisions made by the state.

Social stratification is recognized archaeologically by the existence of site hierarchies, differentiation in burials, presence of sumptuary goods, and monumental architecture. Isbell and Schrieber (1978) claim that at least four levels of sites are needed to distinguish a state level society archaeologically. First order sites are the largest, most complex sites, and are the fewest in number. Size and complexity decline as numbers of sites increases. For instance, fourth order sites would be quite small, but present in large numbers on the landscape. These criteria are often established through extensive surveys (*e.g.* Isbell and Schrieber 1978; Stanish *et al.* 1997), which are practical from an archaeological standpoint.

The appearance of prestige goods in restricted contexts is often used to argue for the presence of an elite class. Prestige goods may include exotic or rare materials or items, or objects that require a substantial investment in time and/or skill to produce (see Stanish 2003:27). The contexts of these finds should also be considered; if all sites or structures show the presence of these goods, perhaps they were not only the domain of the elite. Differences in burial forms and grave goods is one oft-cited way to establish this archaeologically.

Archaeological correlates of statehood often include the presence of monumental architecture, which suggests the organization and mobilization of a substantial labor force by an elite class. In the case of western South America, monumental architecture is seen as preceding, not defining, the state, as large labor sources may be coerced through a communal ideology (Stanish 2001).

Three Models of the Development of Tiwanaku

A number of models have been proposed to explain the origins of the Tiwanaku state. Most models attempt to track the emergence of each key feature of the state, such as surplus agricultural production. The three main models of Tiwanaku state formation emphasize the importance of agricultural intensification, trade and exchange, and social factors.

One of the earliest, espoused by Bolivian archaeologist Ponce Sangines (1975) followed Childe's (1950) notion of an 'Urban Revolution', whereby surplus production and the creation of a city were the prime movers in state formation. All social, political, and economic changes occur as a result. This model, based on Near Eastern states and

culture history framework, has been largely replaced by more modern explanations, and will not be discussed further here.

Kolata (1986, 1993, 1996, 2003a,b) and colleagues hold that state level organization arose at Tiwanaku as a result of organization and control of agricultural production. He posits that Tiwanaku was based on extensive raised field systems, a highly productive agricultural technology. The intensification of raised field agriculture accounts for the rise of the polity. Likewise, when the technology is compromised during a centuries long drought, the Tiwanaku state collapses (Ortloff and Kolata 1993; Kolata and Ortloff 1996).

Raised fields have received much scholarly attention in the last two decades (Denevan 2001), and form the basis of Kolata's argument. Raised field technology utilizes irrigation canals and mounding to increase temperatures in the planting surface, provide water, and support an algal population that later serves as organic fertilizer (Erickson 1988; Kolata and Ortloff 1996). Experimental results indicate that yields drastically improve using raised field technology. However, a great deal of labor expenditure is required for initial construction and maintenance (Erickson and Candler 1989). Kolata argues that control over and organization of the labor force was essential in the rise of Tiwanaku. By controlling agricultural production, Tiwanaku was able to manage the agricultural surplus, and rise to prominence (Kolata 1986, 1993).

Stanish (1994, 2003) sees raised field agriculture as an essential element in the evolution of political economy. He sees the state as organizing labor in a different, more efficient manner, which leads to generation of surplus without extensive increases in the

amount of work. While individual holds lose some control over production, they are coerced into relationships with elites through ritual and/or politics.

Dillehay and Núñez (1988) and Browman (1978) posit that long distance trade was the main factor in the emergence of state level society. The highland Andes has long been considered the homeland of domesticated camelids, which provide a ready source of wool and meat (Lynch 1983; Moore 1989; Wheeler *et al.* 1976). Importantly, the animals are used extensively as pack animals throughout the Andes. As economic ties between Tiwanaku and its outliers spread, so did ideology and social values. Eventually, the result of this slow and gradual spread and intensification is the appearance of state level organization.

Albarracin-Jordan (1996) accords elite control over the organization of labor a less active role. His 'integrated nested hierarchies' model uses Andean *allyu* organization as a model for prehistoric social identity. Erickson (1988, 1993, 1999, 2000) and Graffam (1992) argue this *allyu* level of organization would have been more than sufficient to control raised field agriculture. Ties between groups would have been maintained through public ritual and ceremony and eventually lead to integration (Albarracin-Jordan 1996). Bandy (2004) accords public ceremonialism associated with the Yaya-Mama Religious tradition a critical role in unification of pre-Tiwanaku polities. Hastorf (2003) suggests, based on evidence from Chiripa, that ancestor cults may have been an integral part of this development.

Each model places different values on economic, social, and political factors. Kolata's (1986) model accords control of surplus agricultural production prime significance. Stanish (2003) extrapolates this assumption further, by attempting to explain

how elites may have coerced local populations into different forms of production. Browman (1978) sees trade as a crucial element. Albarracin-Jordan (1996) sees state society as the logical outcome of the integration of nested hierarchies, solidified through public ceremonialism (Bandy 2004; Hastorf 2003).

Archaeological Predictions

Each model for the origins of the Tiwanaku state must be testable archaeologically to have relevance. Although many researchers have based their models on archaeological evidence, some models are more testable than others. Table 1 outlines the expected archaeological patterns for each main model, and suggests ways in which microfossil analysis can contribute to understanding this important process. This table does not represent an exhaustive or mutually exclusive list of archaeological evidence that may support each model. Rather, it provides a useful framework by which to think about and evaluate each model.

Table 2.1: Archaeological and Microfossil Indicators of Models of Tiwanaku Development

Model	Predicted Archaeological Indicators	Predicted Microfossil Signature
Kolata: Control of agricultural surplus	Increase in raised field production Large scale agricultural feature construction Standardized organization on the landscape Large scale storage facilities Feasting (Stanish)	Appearance of new or varied crop plants or varieties Tightening of crop assemblage Weedy plants Exotic or rare plants
Browman/Dillehay and Núñez: Trade through caravans	Increase in exotic goods in Tiwanaku Increase in Tiwanaku goods throughout region Iconographic depiction of trade activities Hallucinogenic plants	Exotic plants (*e.g.* maize) Hallucinogenic plants
Albarracin-Jordan: Nested hierarchies Bandy/Hastorf: Social integration	Settlement pattern similar to *allyu* organization Urban architecture shows *allyu* patterning Feasting and ritual paraphanelia Public ceremonial architecture	Trade plants from other ecozones Hallucinogens on ritual artifacts/spaces Other exotic plants Restricted use of certain plants

Archaeobotanical analyses have a great deal to add to this debate, since many models depend in large part on the cultivation or procurement of plants. Agricultural intensification may involve the addition of new cultigens, or perhaps a more specific narrow focus on specific taxa. Certain plants, such as hallucinogens, fruits, or maize, may have been traded into the region. Finally, ritual activities may have involved the use of hallucinogenic or exotic plants. Disentangling the role of each of these factors (agricultural intensification, trade, and social/ceremonial elements) using microfossil evidence may be possible with detailed comparison of assemblages from different contexts. However given the complexity of the models presented above, only consideration of several forms of data (*i.e.* faunal, ceramic, isotopic, and lithic) would fully address the issues at hand.

ANTECEDENTS: THE FORMATIVE PERIOD IN THE TITICACA BASIN

During the Formative period, major historical changes take place that form a foundation for the later emergence of the Tiwanaku state around AD 400. The Formative period (1500 BC-500 AD) in Bolivia is divided into Early, Middle, and Late periods (Janusek 2003; Stanish 2003), corresponding roughly with Initial Period, Early Horizon, and Early Intermediate Period in the Peruvian chronology created by Rowe (1960) (Figure 2.1). For the purposes of this discussion, concentration will be on the Middle and Late periods, with some mention of Early Formative. The focus will be on discussing major trends in the archaeological record, and archaeobotanical evidence for these changes. The location of major sites is illustrated in Figure 2.2.

Figure 2.1: Cultural Chronology and Major Sites in the Titicaca Basin

	ANDES (Peru)	TITICACA BASIN	TARACO PENINSULA	MAJOR RELEVANT SITES
1500 AD	LATE HORIZON	Late Horizon	Pacajes-Inka	
	LATE INTERMEDIATE PERIOD	ALTIPLANO	EARLY PACAJES	
1000 AD	MIDDLE HORIZON	MIDDLE HORIZON	TIWANAKU 4&5	Tiwanaku, Lukurmata Influence of Tiwanaku extends to northern Chile and southern Peru
500 AD	EARLY INTERMEDIATE PERIOD	LATE FORMATIVE	TIWANAKU 3	Tiwanaku
			TIWANAKU 1B	Pukara, Kala Uyni
0 BC/AD			TIWANAKU 1A	Pukara, Kala Uyni
500 BC	EARLY HORIZON	MIDDLE FORMATIVE	LATE CHIRIPA II	Chiripa, Pukara, Qaluyu, Canchacancha-Asiruni, Wankarani, Uspa-Uspa, San Andres, Tiwanaku?
			LATE CHIRIPA I	Chiripa, Qaluyu, Canchacancha-Asiruni. Wankarani, Uspa-Uspa, San Andres
1000 BC	INITIAL PERIOD	EARLY FORMATIVE	MIDDLE CHIRIPA	Chiripa
1500 BC			EARLY CHIRIPA	Chiripa, Quelcatani, San Bartolomè-Wiscachani
2000 BC				

Sources: Hastorf 1999; Kolata 2003; Stanish 2003; Whitehead 1999a

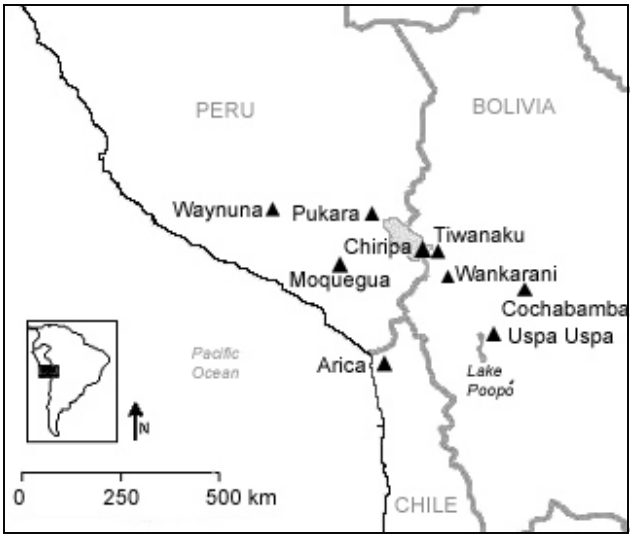


Figure 2.2: Map of South Central Andes and Major Sites Mentioned in Text

Early Formative (2000-1300 BC)

The beginning of the Formative period is signaled by permanent village life focused around lake edges and springs. There is no evidence for agriculture or pastoralism until the end of this period. On the basis of climatic data, Binford and colleagues (1996) suggest that wetter conditions necessary for agriculture were not in place until 3400 BP. No raised field formations are found during the period, and settlement patterns suggest a lacustrine focus (Stanish 2003). Pottery appears by 3660 BP (2000 BC cal) at Quelcatani (Steadman in Stanish 2003:102). Stanish (2003) reports petroglyphs at the site of San Bartolomè-Wiscachani that may represent mountain worship, but the evidence for ritual activities is slim for this period. Evidence for cermemonial architecture does appear in the neighboring southern Peruvian highlands at the site of Asana, dating to 4600 BP (Aldenderfer 1990). In addition, there is evidence in the Titicaca basin that obsidian was already being acquired from quite a distance (Burger *et al.*2000; Stanish *et al.* 2002; Stanish 2003). This period as a whole is not well

investigated, complicated by the fact that most early sites are buried by later occupation. Most of the data available seems to be based on site surveys, rather than excavations. Consequently, no archaeobotanical studies have been completed for this period, with the exception of Chiripa (Bruno and Whitehead 2003; Whitehead 1999b).

Middle Formative (1300-500 BC)

The Middle Formative is associated with the appearance of ranked society. Three tiered settlement hierarchies appear. Regional centers emerge, defined by the presence of corporate architecture and larger size. Typically they include sunken courts, stone stelae, and elaborate mounds (Stanish 2003). The first (dated) evidence for raised fields appears by 1000 BC (Erickson 1987). Developments take slightly different trajectories to the north, south, and stretch down to Lake Poopó in southern Bolivia.

The northern portion of the Lake Titicaca basin is not well known during this period. The Middle Formative is called Early Qaluyu, after the type site. The site of Qaluyu is estimated to have a 7 ha occupation, at least five sunken plazas, and terraced habitation areas. Unfortunately there is some confusion over the dates of these structures, which may, in fact, belong to the later Pukara period. The site of Pukara is also occupied during the period, but little else is known (Kolata 1993; Stanish 2003). The much larger site of Canchacancha-Asiruni, estimated at 12 ha in size, suggests that Qaluyu may represent a more peripheral settlement, instead of a regional center (Chávez and Chávez 1970; Stanish 2003).

To the south of Lake Titicaca the most famous archaeological site is Chiripa (Figure 2.2). Chiripa continued to be occupied during the Middle Formative, and became one of the first ranked polities in the region. During the Early Chiripa phase (1500-1000

BC) (Whitehead 1999a), domestic activity areas are present, which contain guinea pig offerings, fine ceramics, burials with offerings, and sodalite beads, suggesting that ritual activity was an important part of everyday life (Dean and Kojan 1999). Among other taxa, domesticated quinoa (*Chenopodium quinoa*) dates to 1500 BC at Chiripa from domestic midden contexts (Bruno and Whitehead 2003:346). Additionally, general similarities exist between Wankarani and Chiripa pottery during this early phase (Kolata 1993; Ponce Sanguines 1975).

Some suggest that the site of Tiwanaku was first occupied during this period, which is referred to as the Tiwanaku I or Chiripa phase. However there is only one early date for occupation of the site at this time, and traces of habitation are obscured due to extensive construction later in time (Stanish 2003). If occupied at this time, it is clear that Tiwanaku is not yet a major site. On the Island of the Sun during the Middle Formative the number of sites increases and their distribution suggests two distinct groups inhabit the island. Chiripa pottery, as well as exotic lithic material, also dates to this period, suggesting extensive linkages with the mainland (Stanish 2003).

Importantly, the Yaya-Mama religious tradition emerges during the later part of the Middle Formative. The Yaya-Mama religious tradition is characterized by temple-storage complexes, ritual paraphenilia, supernatural iconography characterized by rayed appendages and a divided eye, and a particular style of stone stelae often found at temple complexes (Chávez 1988:17). In the Middle Formative there is evidence of Yaya-Mama style of stone stelae, and ceramic trumpets that probably had a ritual function (Hastorf 2003; Stanish 2003; Stanish and Steadman 1994). In fact, there is a clear shift from undecorated stone stelae in the Early period to decorated, Yaya-Mama style stelae near

the end of the Middle Formative (Stanish 2003: 131-132). The supernatural iconography is apparently not developed until a little later, and there is no evidence for temple storage complexes until the next period.

Stretching from Tiwanaku south all the way to Lake Poopó, the Wankarani culture was organized into small villages during this time (Figure 2.2). The inhabitants probably had a mixed agropastoral subsistence, as attested to by camelid, fish, and fowl remains (Bermann and Estevez Castillo 1995; Kolata 1993). The first evidence in the Andes for copper smelting is found at these sites. Llama head effigies are also found during the period, and although they are likely indicative of some ritual activities (Bermann and Castillo 1995), they probably did not represent a corporate art style (Kolata 1993). Few sites have been excavated; Wankarani, Uspa-Uspa (Figure 2.2), and more recently San Andres, are the best known (Bermann and Castillo 1995; Kolata 1993; Ponce Sangines 1970)

More sites are known, but only by survey, so there is a limited amount of information available. Settlement pattern data do come in handy to address site size hierarchy and site distribution by ecotone (Albarracin-Jordan 1996; Stanish *et al.* 1997). In the Juli-Pomata region in the southwestern Lake Titicaca basin, Stanish and colleagues (1997) demonstrate that most settlements are located on the lake edges, and some in potential raised field agriculture zones. Locating Middle Formative occupations is often problematic, however, due to later occupations on the same sites (Stanish 2003).

Late (Upper) Formative (500 BC-400 AD)

In the Middle Formative there is good proof for ritual activity at the level of household, especially at Chiripa and Wankarani sites. During the Late Formative this

activity expands in the form of ceremonial architecture, the full blossoming of the Yaya-Mama religious tradition, and the ubiquity of ritual vessels and large-scale ceremonial sites. These developments are best illustrated by discussing the sites of Chiripa, Tiwanaku, and Pukara.

The Late Chiripa phase (800 BC-100 BC) at the Chiripa site straddles the Middle and Late Formative transition. Major construction works include the mound, temple-storage complex, rectangular sunken court, and the Llusco structure. The temple-storage function of the main complex is partially based on its unique architecture, which include elaborate doorways, interior windows that lead into bins, wall niches, double walled construction, inset doorways, and yellow clay floor and walls (Chávez 1988:25). The Llusco structure is hypothesized to be a group ceremonial structure, due to the high density of ceramics associated with ritual activities (Paz Soria 1999). Chiripa ceramics are spread throughout the region at this time, as far north as Pukara (Kolata 1993; Stanish 2003).

In and around Tiwanaku, the Kalasasaya tradition is followed by the Qeya tradition. The Kalasasaya Complex (or Tiwanaku I) dates to 300 BC through 200 AD, representing the first solid occupation at Tiwanaku. It is characterized by stone lined sunken courts, a 'Kalasasaya-like stone enclosure', and often, an adjacent pyramidal hill. These features are found at Chiripa, Pukara, and expanded on later at Tiwanaku. Yaya-Mama stelae and pottery associated with elites continue to be present at regional centers (Stanish 2003:141-142). The Qeya period (100-?400 AD) extends from the end of Kalasasaya to the formation of the Tiwanaku state. There is a population increase in the Tiwanaku valley itself, and a decrease outside the area throughout this period

(Albarracin-Jordan 1996, 2003). The presence of diagnostic ceramics for the period is problematic, however (see discussions in Albarracin-Jordan 1996: 189-191; Stanish 2003:139). At the site of Tiwanaku itself, it is also difficult to identify architectural features belonging to this early period, due both to later occupations and confusion in defining this period (Janusek 2003). For these reasons, Pukara often serves as the analog for understanding early Tiwanaku (Stanish 2003).

Pukara rises to its height during this time (200 BC-200 AD) (Figure 2.2, 2.3) (Kolata 1993). Stanish (2003:142) remarks that it is "one of the most important and least published major sites in the Titicaca basin." Indeed, the site of Pukara itself is thought to encompass 2 km^2, and is made up of series of large terraces that lead to a sunken court at the top. More courts surround the terraced area, and are lined with stone slabs. The site contains both residential and ceremonial components. Ornate stone sculpture, finely dressed stone masonry, and decorated incised pottery are best known, and resemble later Tiwanaku materials (Chávez 1988; Stanish 2003). A comparison with the temple storage complex of Chiripa suggests cultural ties (Chávez 1988). The depiction of trophy heads and discovery of hundreds of human skeletons in a ritual area, imply sacrifice, raiding, or reburial of some sort. The Pukara polity spreads throughout the northern Lake Titicaca basin, and is thought to represent one of the earliest manifestations of a corporate art style (Kolata 1993; Stanish 2003).

As mentioned previously, so little is known about Tiwanaku in this period that it is hard to compare it to Pukara. What is clear is the end result; Pukara falls by 200 AD, and Tiwanaku is a state by around 500 AD. Some researchers have theorized that Tiwanaku's rise to statehood occurred because there was little resistance in the south,

whereas Pukara had much competition in the north. Most would probably agree that Pukara and Tiwanaku were competitive peer polities, as they share many stylistic attributes and iconographic depictions, like the trophy head motif (Chávez 1988; Kolata 1993; Stanish 2003).

Understanding the Late Formative is crucial for explicating the origins and rise of the Tiwanaku state. Unfortunately methodological problems inhibit investigations at Tiwanaku itself. From excavations at Chiripa and Pukara, as well as extensive surveys in the Tiwanaku valley, Juli-Pomata region, and recently, the Taraco Peninsula (see below), it is clear that this is a time of emerging social, ritual, and economic complexity.

ARCHAEOBOTANICAL ISSUES IN THE FORMATIVE PERIOD

> If archaeobotanical criteria are used instead of ceramic criteria to define cultural units, the results would be different.
>
> -Browman 1986:147

Plant remain evidence can also be used to add to our understanding of subsistence, trade, and ritual life in the Lake Titicaca basin; however few archaeobotanical studies to date have focused on these issues. This is surprising in light of the relevance of plant evidence for changes in agricultural strategies, potential use of hallucinogenic plants for ritual purposes, and suggested trade links, which may have involved maize, among others. Below the archaeobotanical record is briefly outlined, with a specific focus on the Lake Titicaca basin. Evidence outside this region for specific crops will be discussed in the following chapters, which weigh information concerning subsistence, hallucinogenic and exotic plants, as well as maize, more fully.

Altiplano agriculture relies on the production of several indigenous crops adapted to the high elevation environment. These include potato (*Solanum tuberosum*), oca (*Oxalis tuberosa*), isanu (*Tropaeolum tuberosum*), papalisa (*Ullucus tuberosus*), beans

(*Phaseolus* and *Lupinus*), cañihua (*Chenopodium pallidicaule*), and quinoa (*Chenopodium quinoa*). Maize (*Zea mays*) is cultivated in low quantities, but is restricted to the lake edges (Wright *et al.* 2003: 187). The antiquity of these domesticates is unknown, except in the case of quinoa (see below).

While several paleoethnobotanical projects in Bolivia are currently underway (M.C. Bruno pers. comm. 2004, K. Killacky pers. comm. 2004), information available concerning prehistoric subsistence and agricultural production is still limited. The best examples are from Chiripa (Browman 1986; Bruno and Whitehead 2003; Erickson 1977; Whitehead 1999b), sites on the Copacabana peninsula (Lee 1997), and Lukurmata and Tiwanaku (Wright *et al.* 2003) (Table 2.2). Two recent microfossil studies in the Andes are highlighted to show the utility of the approach.

Browman (1986) and Erickson (1977) report on results of archaeobotanical analysis at the site of Chiripa on the Taraco Peninsula. Samples were dominated by *Chenopodium*, followed by wild grass, and other wild plants in the Malvaceae, Amaranthaceae, Cactaceae, Cyperaceae, and Juncaceae, among others (Table 2.2). *Chenopodium* ranked at 100% ubiquity across contexts, accounting for 70-88% of the assemblage (Browman 1986:142). Several tuber fragments were also present in the flotation samples, but are not identified or quantified further (Browman 1986). However, early analysis by Towle (1961) of materials excavated at Chiripa by Kidder include potato (Towle 1961:84), with reanalysis suggesting that *Oxalis tuberosa* and *Ullucus tuberosus* were also present (Towle pers. comm. in Browman 1986:149).

Whitehead (1999b) reports on macrobotanical remains recovered at Chiripa. *Chenopodium* dominates most samples, and a number of wild species, especially grasses,

are also present in sizeable quantities. The analysis also indicates that floors in two areas (Monticulo 1 and Llusco enclosure) seem to be quite clean, indicating that these may represent special (non-domestic) use structures, in contrast to Santiago (B16 surface), where charred plant remains are far denser.

Bruno and Whitehead (2003) focus on distinguishing cultivation practices and domestication of *Chenopodium*. Using a combination of testa thickness, surface texture, and margin configuration, they are able to separate domesticated quinoa from wild/weedy *quinoa negra*, and demonstrate the presence of a crop/weed complex by 1500 BC. In addition, the quantities of quinoa and *quinoa negra* seem to shift over time, with more *quinoa negra* being present in Early and Middle Chiripa contexts, and significantly less in Late Chiripa times. This suggests more intensive selection and/or weeding practices were in place by the Late Chiripa period (Bruno and Whitehead 2003).

Macrobotanical analysis focusing on five Yaya-Mama sites on the Copacabana peninsula, on the Peruvian side of Lake Titicaca, is also instructive (Figure 2.3). Lee (1997) reports that finds were dominated by Cheno-Am (*Chenopodium* and/or *Amaranthus*), wild grasses, *Trifolium*, and Malvaceae. Fragments of root/tuber tissue, identified as potato and oca, were also present in moderate amounts, although it is not known whether they represent wild or domesticated species. Lee also reports the presence of fragments of freeze-dried tubers (*chuño*), and one kernel and one glume of maize (Table 2.2). These finds are quite similar to those reported at Chiripa (Browman 1986; Whitehead 1999b), but may reflect less reliance on domesticated quinoa. Recent phytolith analysis at the same sites has suggested the presence of maize on four pot sherd residues, dating to 2750-2410 BP (Chávez and Thompson 2006: 425). Although not available until

after the completion of the present study, Chávez and Thompson's (2006) findings bear direct relevance and are evaluated more fully in Chapters 7 and 8.

Paleoethnobotanical analysis was conducted at Tiwanaku, Lukurmata, and Tiwanaku Valley sites as part of the Wila Jawira project (Kolata 2003; Wright *et al.* 2003). Quinoa dominates the assemblage overall in percentage presence[1], at 93%. Maize occurs in relatively high amounts (25 percentage presence), which is rather surprising considering that maize cannot be cultivated in the Tiwanaku Valley. However, based on a maize variety study, Hastorf *et al.* (2006) show that maize was traded into Tiwanaku, probably from lower lying valleys more suited to maize cultivation. While maize cannot be grown in the Tiwanaku Valley, it is possible in areas closer to the lake, due to microclimatic effects which act to increase available moisture as well as the number of frost free days (Binford *et al.* 1997; Hastorf *et al.* 2006)[2]. Tubers occur in only 5% of samples, which is probably a function of preservation constraints, but also may represent low overall usage or variable processing, as other highland Peruvian contexts have yielded high percentage presence of tubers (Hastorf 1993). Legumes are present in 1% of contexts, perhaps a reflection of differential preservation rather than low usage (Wright *et al.* 2003: 387-388). Relatively large amounts of wild seeds overall may be reflective of crop processing, use of dung as fuel, or preservation considerations (Wright *et al.* 2003:389-390). Comparisons between Tiwanaku, Lukurmata, and Tiwanaku Valley sites show some interesting patterning. First, Tiwanaku had the highest maize presence, suggesting variable access to the crop. *Chenopodium* occurs in large amounts in most

[1] Percentage presence describes the percent of contexts a particular taxon is found in, in other words, quinoa is present in 93 out of 100 cases, or 93%. It is useful for talking about how common usage of a particular plant is, although it does not address the absolute quantity of that plant (Popper 1988).
[2] See Chapters 6 and 7 for a full discussion of the maize issue.

Table 2.2: Macrobotanical remains identified in the Titicaca region

Family	Genus/Species	Site
Amaranthaceae	*Amaranthus* sp.	Chiripa, Copacabana
Asteraceae	Unknown	Chiripa, Lukurmata, Tiwanaku
Boraginaceae	Unknown	Chiripa, Lukurmata, Tiwanaku
Brassicaceae	*Lepidium* sp. Unknown	Chiripa Chiripa
Cactaceae	*Cereus* sp. *Opuntia* sp. Unknown	Chiripa, Copacabana, Lukurmata, Tiwanaku Copacabana Chiripa, Lukurmata, Tiwanaku
Caryophyllaceae	Unknown	Lukurmata, Tiwanaku
Chenopodiaceae	*Chenopodium pallidicaule** *Chenopodium quinoa** *Chenopodium negra* *Chenopodium* sp.	Chiripa, Lukurmata, Tiwanaku Chiripa Chiripa Chiripa, Copacabana, Lukurmata, Tiwanaku
Convolvulaceae	Unknown	Copacabana sites
Cyperaceae	*Scirpus* sp. Unknown	Chiripa, Lukurmata, Tiwanaku Lukurmata, Tiwanaku
Euphorbiaceae	Unknown	Chiripa
Fabaceae	*Lupinus* sp. *Trifolium* sp. Unspecified/various** Wild type	Copacabana sites Copacabana sites Lukurmata, Tiwanaku Chiripa, Lukurmata, Tiwanaku
Iridaceae	*Sisyrinchium* sp.	Lukurmata, Tiwanaku
Juncaceae	*Juncus* sp.	Tiwanaku, Lukurmata
Labiateae	Unknown	Chiripa, Lukurmata, Tiwanaku
Malvaceae	*Malvastrum* sp. Unknown	Chiripa Copacabana sites, Lukurmata, Tiwanaku
Oxalidaceae	*Oxalis* sp.	Chiripa, Lukurmata, Tiwanaku, Copacabana
Plantaginaceae	*Plantago* sp.	Chiripa, Lukurmata, Tiwanaku
Poaceae	*Dactyloctenium aegyptium* *Festuca* sp. *Stipa* sp. *Zea mays** Unknown	Chiripa Copacabana sites Chiripa Chiripa, Copacabana, Lukurmata, Tiwanaku Chiripa, Copacabana, Lukurmata, Tiwanaku
Polygonaceae	*Polygonum* sp. Unknown	Copacabana Lukurmata, Tiwanaku
Potamogetonaceae	*Potamogeton* sp.	Chiripa, Lukurmata, Tiwanaku
Rosaceae	*Rubus* sp.	Chiripa, Copacabana sites
Rubiaceae	*Galium* sp. *Relbunium* sp.	Chiripa, Lukurmata, Tiwanaku Chiripa, Copacabana, Lukurmata, Tiwanaku
Solanaceae	*Nicotiana* sp. Unknown Wild type	Chiripa Chiripa Lukurmata, Tiwanaku
Verbenaceae	*Verbena* sp.	Chiripa, Copacabana, Lukurmata, Tiwanaku
Various/Other	Tuber	Chiripa, Copacabana, Lukurmata, Tiwanaku

Compiled from Browman 1986; Bruno and Whitehead 2003; Lee 1997; Whitehead 1999b; Wright *et al*. 2003, * Domesticate ,**Refers to various probably domesticated species (*e.g. Phaseolus, Lupinus*), Copacabana refers to 3 sites on Copacabana peninsula (Lee 1997).

contexts, with the greatest density at Lukurmata. Finally, Tiwanaku yielded slightly greater quantities of tubers and legumes overall (Wright *et al.* 2003:390).

One other microfossil study has been published for the central Andean region, but it demonstrates the utility of the approach, and serves as an interesting comparison for the present study. Perry *et al.* (2006) reports on the analysis of phytolith and starch grains from both soils and artifacts in a late Preceramic house (3600-4000 cal. BP) at the site of Waynuna (Peru) (Figure 2.2) (Perry *et al.* 2006:77). Waynuna is in the middle of two distinct elevational zones: 1) 2300-3600 masl: suitable for irrigated maize production, and 2) 3600-4000 masl, which is dominated by tuber cultivation. Starch was recovered from soil in large amounts, yielding over 1000 maize starch grains, and small amounts of Marantaceae and cf. *Solanum* sp. starch on groundstone tools. These results were confirmed with phytolith analysis, which showed large amounts of maize, and some conical bodies characteristic of Marantaceae. The authors conclude that the Marantaceae microfossils represent arrowroot probably arrived from the Amazon to the east, instead of the Peruvian coast, showing an early example of trade in lowland plants to the highlands. Importantly, this study firmly establishes maize in the highlands 1000 years earlier than expected, at 3600-4000 cal. BP (Perry *et al.* 2006). The only other comparable dates for maize in the region are from Ayacucho caves at about 3100 B.C., although this is an indirect date—the maize kernels have yet to be directly dated (Pearsall 1992; Pearsall pers.comm.2006).

While significant strides have been made in understanding agricultural and consumption practices in the Formative period and subsequent Tiwanaku eras, many issues still need to be resolved. The most pressing of these is the question of tubers. Due

to preservation constraints, and perhaps taphonomic pressures arising from cooking practices, tubers are present in very low amounts or absent altogether from Titicaca basin archaeobotanical samples. This is despite the fact that the high elevation Andes has long been hypothesized to be the center of potato and tuber domestication, and that extant populations living in the region today are in large part dependent on these important crop plants. Even though the presence of potatoes, and probably other tubers, has been confirmed at Tiwanaku, evidence for when this system developed, and the role of tubers in subsistence, exchange, and possibly, ritual, has yet to be determined.

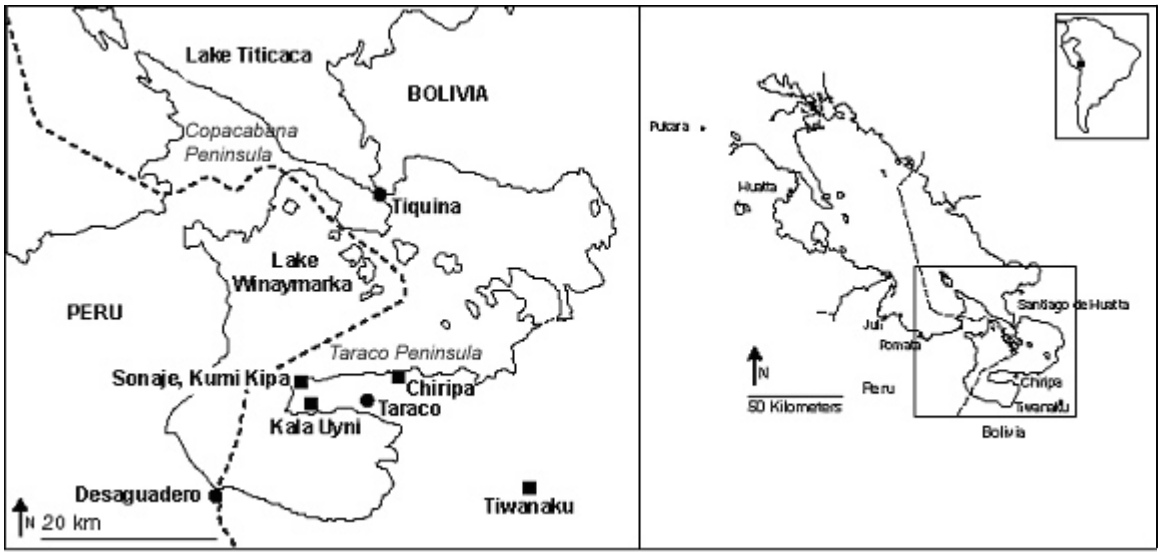
A second issue raised by consideration of the archaeobotanical and archaeological evidence concerns ritual behavior and associated plant use. While Tiwanaku is associated with hallucinogen use, the antiquity and nature of this system has yet to be defined. A third consideration is the function of maize in subsistence, trade, and ritual activity, which appears to play an important role during Tiwanaku times. However, evidence for maize is scarce in Formative period archaeobotanical contexts. These three issues form the basis of the present study, which employs phytolith and starch grain analysis to investigate tubers, hallucinogenic and exotic plants, and maize during the Formative period as part of the Taraco Archaeological Project.

THE TARACO ARCHAEOLOGICAL PROJECT

The Taraco Archaeological Project (TAP), directed by Dr. Christine Hastorf and Dr. Matthew Bandy, has focused on excavation of sites on the Taraco Peninsula since 1992 (Figure 2.3). The Taraco Peninsula is a thin stretch of land that juts into Lake Winaymarka, at approximately 3800 m.a.s.l.. The peninsula is in close proximity to Tiwanaku, and ecologically can be characterized as altiplano.

The first phase of the project focused on excavation of Chiripa (1992-1999) (Hastorf 1999). Extensive survey of the peninsula by Bandy in the late 1990s (Bandy 2001, 2004) delimited additional important sites of the Formative period. The second phase of TAP focused on excavation of three of these sites, near the tip of the peninsula: Kala Uyni (2003, 2005), Sonaje (2004, 2005), and Kumi Kipa (2004).

Figure 2.3: Map of the Lake Titicaca basin and study region



Modified from Taraco Archaeological Project website (http://andean.kulture.org/tap/)

Bandy (2004) tracks village fissioning events on the Taraco Peninsula during the Formative period. In the Early and Middle Chiripa periods (=Early Formative), villages fissioned once they reached a population threshold of about 150. By the Late Chiripa period (=Middle Formative), towns continued to grow in size, but village fissioning ceased. About the same time, there is evidence for the emergence of the Yaya-Mama Religious Tradition (Bandy 2004; Hastorf *et al.* 2005). Based on this, Bandy (2004) hypothesizes that the Yaya-Mama Religious tradition, with its emphasis on public ceremonialism, served a socially integrative function.

By Tiwanaku 1 times (=Late Formative) the pattern changes; many villages suffered major population loss, but one village on the peninsula, Kala Uyni, grew significantly, perhaps signifying political dominance over the region. Bandy *et al*. (2004) and Hastorf *et al.* (2005) refer to this as the Taraco Peninsula Polity. The social and economic processes that led to the formation of the Taraco Peninsula Polity, and the implications this may have for understanding the development of the Tiwanaku state, is the primary research focus of the Taraco Archaeological Project.

TAP excavations have focused at Kala Uyni (2003, 2005), and the smaller, neighboring sites of Sonaje (2004,2005) and Kumi Kipa (2004). Through a series of specialist analyses, including ceramic, zooarchaeological, archaeobotanical, and soil studies, the Taraco Archaeological Project seeks to examine the formation of multicommmunity polities in the region. Specifically, the project addresses the role of three hypotheses put forward to explain the development of the Tiwanaku state (see above): 1) subsistence intensification, 2) trade, and 3) ritual and public ceremonialism. The Taraco Peninsula is an ideal location to test these hypotheses, because 1) there is early evidence for the development of many of these traditions at Chiripa (Chávez 1988; Hastorf 2003), 2) Bandy's (2001, 2004) work clearly shows population shifts and aggregation during the Formative period, and 3) the sites are located in close proximity to Tiwanaku, and likely had a significant impact on the development of state level society in this region.

Phytolith and starch grain analysis can add to our understanding of the economic and social processes that led to the development of multicommunity polities in the region. As part of the larger Taraco Archaeological Project, this thesis reports on results of

microfossil analysis of artifact residue and soil samples from Chiripa, Kala Uyni, Kumi Kipa, and Sonaje. The aim is to document plant indicators associated with subsistence, trade, and ritual that would otherwise not be represented in the macrobotanical record. In this way, phytolith and starch grain analysis can help disentangle the complex processes that led to the formation of the Tiwanaku state.

CHAPTER SUMMARY

Tiwanaku, the first pristine state in highland Bolivia, appears by about AD 400. Raised field agriculture, extensive trade in exotic materials, and complex ritual activities are major parts of this system. Three models have been put forward to explain the development of the Tiwanaku state. The first model accords agricultural intensification prime significance. Alan Kolata and colleagues suggest that the development of large scale raised field systems, and their control by the elite, allowed for the construction of monumental architecture and support of large populations. A second model holds that a complex ceremonial industry, involving rich iconographic depictions and perhaps psychoactive plants, served a socially integrative function, allowing for the formation of multi-community polities in the area. Finally, David Browman and others suggest that wealth generated by caravan trade allowed for the emergence of a controlling elite.

The antecedents to Tiwanaku, located in the Formative period of the Titicaca Basin, are reviewed in light of these models. By the Middle Formative period there is evidence for domesticated quinoa and emergence of the Yaya-Mama Religious tradition. Archaeobotanical work in the region is limited to the sites of Chiripa, Tiwanaku, and Lukurmata, and suggests that quinoa played an important role. By Tiwanaku times imported maize plays becomes important.

The Taraco Archaeological Project focuses on evaluation of these three factors (agricultural intensification, trade, and ritual/social phenomena) through excavation of Formative period sites and a series of specialist analysis. Phytolith and starch grain analysis can add to our understanding of state formation by tracing subsistence, ritual and exotic, and trade plants.

CHAPTER 3
GENERAL METHODS AND RESULTS

INTRODUCTION

This chapter discusses general methods used for the processing and analysis of phytolith and starch grain comparative and archaeological samples. Results are also communicated in a general form at the end of the chapter, although specific results are discussed in Chapters 4, 5, and 6. Only basic information is presented here; more specific information relevant to each research question is reported in the chapters to follow.

CALCIUM OXALATE

One objective of this study was to evaluate the potential for using calcium oxalate crystals to identify plants archaeologically. The first component focused on modifying current processing procedures for comparative and archaeological samples, which involve the use of acids that disintegrate calcium oxalate (Coil *et al.* 2003). The second portion of the study involved the development of methods, including identification criteria, for the analysis of calcium oxalate. In addition to basic methods, this chapter reports the changes that were made to current processing techniques, corresponding analysis methods, and the potential for archaeological applications of calcium oxalate crystals.

COMPARATIVE PLANT STUDIES

Comparative plant studies were conducted in order to identify potential diagnostics for plants of interest, assess identification methods developed for other regions, and address the feasibility of using calcium oxalate crystals for identification of specific plants.

Processing Methods

Chemical processing techniques normally used at the MU Paleoethnobotany laboratory involve cleaning comparative plant material with detergent, and rinsing the reagent off using a Buckner funnel set up. Schulze solution (three parts nitric acid, one part potassium chlorate) is added, and the specimen is placed in a hot water bath until the plant material is digested. This is followed by warm rinses in nitric acid, distilled water, hydrochloric acid, and distilled water again (Pearsall 2000).

However, both nitric and hydrochloric acid dissolve calcium oxalate (Coil *et al.* 2003); as such an attempt was made to formulate a new calcium oxalate friendly procedure. Both 27% hydrogen peroxide and glacial acetic acid were used, warm and cold, for a number of weeks on end. However, neither chemical was strong enough to digest the plant material. Therefore, we returned to the dry ashing technique (Pearsall 2000), which allows extraction of silica and non-silica crystals alike (Coil *et al.* 2003; Korstanje 2001). Dry ashing involves pretreatment or cleaning of plant tissues, after which the material is dried in a low temperature (100º C) oven. Plant material is then subjected to 400-500º C heat in a muffle furnace until it is reduced to ash, usually about 2-5 hours. Organic material is burnt away, leaving silica and calcium compounds.

Comparative Plants

A comparative collection of Bolivian plants was derived from three main sources: M.A. Korstanje's Andean comparative collection, plants collected by A. Logan in Bolivia in 2004, and additional species from the Missouri Botanical Garden and the University of Missouri Herbarium. Most plants were processed using the dry ashing technique at MU, with the exception of a few grasses that were processed using the normal chemical

method (as calcium oxalate crystals in the grasses were not of interest). Korstanje (2001) also used a dry ashing technique, followed by a rinse in 10% acetic acid.

All comparative phytolith slides were mounted in immersion oil and sealed with nail polish using a toothpick. All comparative samples were scanned using a Nikon Labophot microscope at 400x magnification. Calcium oxalate was observed in both comparative and archaeological samples using cross-polarized light at 400x magnification. Pure calcium oxalate crystals appears gold to multicolored under polarized light, while calcium carbonate appears dull white to blue. Calcium oxalate crystals were also much different morphologically from calcium carbonate and other materials. Following a classic work on calcium oxalate (Franceschi and Horner 1980), two size variants (small and large) for each of five shape classes were recognized (crystal sand, druse, prism, raphide, and styloid). Abundance values were determined for each of these categories of calcium oxalate in comparative samples.

Grass comparative phytolith assemblages were characterized using existing MU short cell counting forms, and additional new phytolith forms were noted on a separate page. Short cell forms were recorded to a count of 50. While a count of 200 short cells is typical for characterization of archaeological soil samples, grass comparative samples represent a pure assemblage from one taxon, instead of a mixed group encountered in soil samples. In addition, given the large number of grass taxa analyzed (>100), it was not possible to do larger counts. Non-grass comparatives were scanned and counted using a blank form until redundancy was reached.

For starch grain comparative samples, no processing was conducted. Slides of tuber species were made in the field with the help of M. Bruno and J. Capriles, using a

clean knife to cut and scrape the tuber, and smearing the material on a slide. The instruments were all washed with alcohol between samples. At MU, additional starch mounts were made by crushing plant material, depositing a small amount on the slide and mixing it with 4 drops of 50:50 glycerol to water solution. Starch slides were examined using standard MU starch forms, and several characteristics were recorded including granule shape and size, and features of the extinction cross, hilum, fissures, outer wall, surface, and presence of lamellae.

ARCHAEOLOGICAL SAMPLES

Two types of archaeological samples were analyzed: soil samples from archaeological sites, and artifact residue samples.

Soil Samples

The current extraction procedure used at the University of Missouri involves the use of acids that are harmful to calcium oxalate. Following suggestions in Coil *et al.* (2003), Zhao and Pearsall (1998), and Karol Chandler-Ezell (pers. comm. 2003), experimental processing was conducted in order to develop a calcium oxalate friendly procedure.

First, preliminary tests were run on pure calcium oxalate crystals for each of the chemicals used in processing. Hydrochloric and nitric acids reacted immediately with the crystals, and no calcium oxalate was present after the reaction ceased. Both hydrogen peroxide and glacial acetic acid showed no visible reaction with calcium oxalate.

With the help of S. K. Collins, two archaeological soil samples (MU 2192, 2195) were divided into five parts each in order to test and modify the procedure. The first two (MU 2192, MU 2195) were run using the normal University of Missouri procedure

(Pearsall 2000). Little to no calcium oxalate was observed in these samples. Next, two variables were tested, the use of glacial acetic acid or water as the liquid agent in heavy liquid flotation, and the use versus non-use of bleach during organic removal. Samples that were floated using the water and zinc iodide solution contained a large amount of precipitated zinc iodide, so glacial acetic acid was chosen as the preferred mixing medium. Short cell counts from both bleach and no bleach samples were similar, suggesting little qualitative difference. However, samples that were processed without bleach yielded more extract. Hence, bleach was taken out of the modified procedure in 2003-2004. After scanning several slides, it was apparent that organic removal was not satisfactory, so the bleach step was added in Fall 2004. This also reduced the reaction time in the subsequent hydrogen peroxide step. Finally, the modified procedure produced a much larger amount of extract when compared to the normal procedure. See the modified procedure in Appendix 1A for more details.

The finalized calcium oxalate friendly procedure involved replacement of hydrochloric and/or nitric acid with glacial acetic acid (see Appendix 1 for full procedure). Carbonate and oxide removal involved the use of glacial acetic acid in a hot water bath. A bleach step usually used to speed up organic removal was omitted from the procedure in 2003-4, but added again in 2004 onwards. Hydrogen peroxide was added to the soil samples and placed in a hot water bath for approximately one to three hours to remove organic material. Heavy liquid flotation was completed using zinc iodide mixed with glacial acetic acid and distilled water.

Calcium oxalate was observed in archaeological samples using the same methods as for comparative plant material (discussed above). Soil samples were mounted in

Canada Balsam, and scanned at 400x using a Nikon Labophot microscope. Alternate rows were examined, totaling 8-10 rows on average. Grass short cells were tallied to a count of 200, after which scanning for other diagnostics continued over the entire slide.

Artifact residues

Artifact residues were sampled and processed using a modified version of the procedure reported in Chandler-Ezell and Pearsall (2003) and Pearsall *et al.* (2004). All artifacts were sampled in the field, hence modifications were made to the normal procedure, which was designed for laboratory settings. Sampling involved collection of three sediments for unwashed artifacts. Sediment 1 was collected by dry brushing an artifact inside a plastic bag. Sediment 2 involved adding a small amount of distilled water and wet brushing the artifact, also inside a plastic bag. Sediment 3 included the addition of more water and subsequent sonication for 5 minutes, inside either a bag or bottle, depending on the size of the artifact. Sediment 1 remained inside a plastic bag; Sediments 2 and 3 were washed into bottles for transport. For previously washed artifacts, only Sediment 3 was collected, and the sonication time was increased to 10 minutes. All artifacts sampled were photographed. The full procedure is reported in Appendix 1B.

Residues were processed using a piggyback procedure designed to efficiently extract starch grains and phytoliths (Chandler-Ezell and Pearsall 2003). Modifications to this procedure included replacement of strong acid (nitric and hydrochloric acids) with glacial acetic acid, as per the calcium oxalate friendly procedure described above. The basic procedure involves deflocculation with 0.1% NaEDTA, dilute hydrogen peroxide (5.75%) organic removal, starch flotation using cesium chloride (specific gravity 1.6 g/mL). While starch flotation is optional, depending on the ‘dirtiness’ of the sample

(Chandler-Ezell and Pearsall 2003), almost all TAP samples required this step. The sample is then easily divided into starch extract, and residue remaining for phytolith extraction. Phytolith extraction follows the same basic soil processing procedure described above and elsewhere (Pearsall 2000), except smaller amounts of chemicals and extraction time are required (Chandler-Ezell and Pearsall 2003).

Starch and phytolith slides were scanned separately. Starch slides were made using a 50:50 mixture of glycerol and extract in water. Alternate rows were scanned for the entire slide using a polarizer; starch is positively identified by the presence of an extinction cross visible under polarized light (Loy 1994). Because starch grains are subject to damage if heated for a prolonged period, scanning of each sample was timed and kept under 30 minutes. Phytolith slides were made using a standard mount (0.001 g) in Canada Balsam. Alternate rows were scanned for each slide, averaging 8-10 rows a slide.

CALCIUM OXALATE EVALUATION

Overall, calcium oxalate was successfully extracted from the soil and artifact residue samples. While calcium oxalate was present in the resulting extracts, for the most part identification was not possible. In the comparative samples, shape categories were only vaguely recognizable. In archaeological samples, it was even harder to discriminate among shape classes. The most common form by far were generalized druses, with little detail visible. At this point, the use of calcium oxalate as an indicator of certain taxa archaeologically does not appear very profitable. Simple presence or absence of calcium oxalate is easily established, but the use of shape categories is as of yet not as promising.

There are a couple explanations for these observations. One is that the processing procedure was successful at extracting calcium oxalate, but did not leave the crystal structure intact (Jones and Bryant 1992). Mechanical or heat damage may explain these observations. Most calcium oxalate observed was amorphous. Modifications to the processing procedure may accommodate this, but more experimentation is needed. All soil samples are dried and ground in a mortar and pestle to homogenize the sample prior to chemical processing; this may cause damage to calcium oxalate crystals. Horrocks (2004) suggests that too many rinses (over 3 times) during deflocculation removes a significant amount of calcium oxalate. This could easily apply to sedimentation as well, which for TAP soil samples often required 5 to 10 rinses. An alternate and probably more promising approach is to sample tools and artifacts. Much less processing is required, removing most sources of potential mechanical and chemical damage. Artifact residues, for instance, are not subject to grinding in a mortar and pestle prior to chemical extraction. Loy (1994), among others, has successfully characterized calcium oxalate crystals in tool residues. The lack of detail observed in druses may also be a function of the mounting medium used. Scanning electron microscopy or other use of other mediums may solve this issue. Finally, little calcium oxalate may be present in comparative and archaeological samples. More comparative work is needed to confirm this, however.

In addition to these considerations, one major constraint on the use of calcium oxalate analysis is the paucity of research on archaeological applications. While a fair amount of literature on calcium oxalate morphology exists in the botanical literature, very little is published in archaeology. Special concerns of archaeologists and archaeobotanists, such as redundancy and multiplicity, are not addressed in any of the

available literature. Essentially, if the processing issues are resolved, extensive comparative studies are required to fully recognize the potential of calcium oxalate for archaeological identifications. A brief foray into characterizing calcium oxalate in all ashed MU comparative specimens was attempted; it was eventually abandoned due the sheer magnitude of time and specimens required to accurately address and document calcium oxalate production. For the remainder of this study, calcium oxalate in comparative and archaeological slides was noted, but at this point it is not possible to make firm identifications based on calcium oxalate structures alone.

GENERAL RESULTS

The primary results of this study are reported in the next three chapters. The purpose of this section is to introduce the reader to the body of data that will be referred to in the pages to follow. Chapter 4 reports on details of starch grain analysis in particular, as well as phytolith evidence for local plants. Chapter 5 focuses on phytolith evidence for exotic plants. Chapter 6 concerns both starch and phytolith evidence for maize and wild grasses. Full data for archaeological samples is reported in Appendix 2; data on comparative plant material can be found in Appendix 3.

Data was derived from three main sources: comparative plant studies, artifact residues, and archaeological soil samples, totaling 309 samples. Investigations of comparative plant material focused on the documentation of phytolith production in local plants, hallucinogens, wild grasses, and Andean maize races. A great deal of time was devoted to comparative plant studies, as this is one of the few microfossil studies to focus specifically on the highland Andes. As such, few diagnostics for local plants or hallucinogens had been previously delineated. The first half of each of the chapters to

follow reports on results of comparative plant investigations. In total, phytolith production was documented in 226 comparative plant slides. Seventy-seven of these were originally processed and analyzed by A. Korstanje (2001), and re-examined by A. Logan in 2004. The majority of the comparative work focused on wild grasses of the high Andes (n=106), hallucinogens (n=25), economic plants (n=13), and Andean maize (n=11). Full comparative plant data are located in Appendix 3.

Artifact residue analysis involved the analysis of both starch grains and phytoliths from a number of different artifact types. Analysis of artifact residues was pursued since many of the plants of interest, such as hallucinogens and exotics, if present, were probably used in small quantities. If used on a particular artifact, one would expect residues from such plants to be concentrated, rather than obscured by background and other plant matter in archaeological soil samples. In addition, artifacts provide protected microenvironments that are conducive to starch grain preservation (Haslam 2005), which form the primary data source about Andean tubers.

A wide range of artifact forms were sampled in order to address a broad array of questions concerning tuber, hallucinogen, and maize utilization. In total, 66 artifacts were sampled from 9 different classes of artifacts. These classes are: manos, metate fragment, stone hoe, slate knife fragments, trompos, human mandibles, llama mandible scrapers, scapula “combs”, ceramic trumpet fragments, whole ceramic vessels, and “crucibles”. In total, 98 samples (combined Sediments 1, 2, 3 for 44 artifacts, washed and unwashed) were collected in 2004, and 44 samples (=22 artifacts) collected in 2005. The majority of these artifacts were sampled in summer 2004 by A. Logan, including objects from Chiripa, Chiripa Quispe, Sonaje, Kumi Kipa, and Kala Uyni. Additional artifacts were

sampled by Dr. C. A. Hastorf from Sonaje and Kala Uyni in 2005. In total, phytolith and starch fractions from 27 artifacts were examined, totaling 63 samples. Starch grain data is presented in Chapter 4, and phytolith data is concentrated in Chapters 5 and 6. Full artifact data is available in Appendix 2A, and photographs of each artifact class are provided in Appendix 2B.

Archaeological soil samples form the remainder of the dataset. In total, 20 soil samples were examined for phytoliths. Soil samples were selected primarily on the basis of contextual association, in the hopes of comparing different results from various areas (*i.e.* ritual versus domestic locales). However, given the lack of phytolith diagnostics for common altiplano plants, this study changed focus to taxa expected to occur rarely, such as hallucinogenic species. Therefore soil samples, which are full of 'background noise' were not the focus of this investigation. Samples were derived primarily from Kala Uyni; none were analyzed from Chiripa or Kumi Kipa. Results are reported in Chapters 5 and 6. Full soil data can be found in Appendices 2C-F.

CHAPTER 4
TUBERS AND NATIVE PLANTS ON THE TARACO PENINSULA

INTRODUCTION

Inhabitants of the Lake Titicaca basin today rely primarily on production of wheat, barley[3], the Andean tubers, quinoa, and maize, as well as a number of lacustrine plant resources. Maize, a non-native plant, is discussed in depth in Chapter 6. While most of these plants are thought to be native to the region, with the exception of quinoa, there are no firm dates associated with utilization and, in some cases, domestication of these important plants. The goal of this chapter is to document phytolith and starch production in many of these local useful and crop plants, and where possible, trace them archaeologically. The focus is on Andean tubers, as these are some of the least documented, and most important, domesticates in the region.

QUINOA AND WILD RESOURCES

Quinoa, as well as wild plants of the grass and sedge families, formed a major part of prehistoric economies on the Taraco Peninsula and the surrounding region, as demonstrated by macrobotanical analysis at the sites of Chiripa (Browman 1986; Bruno and Whitehead 2003; Whitehead 1999b) and Tiwanaku and surrounding sites (Wright *et al.* 2003), as discussed in Chapter 2. This importance, combined with favorable preservation of quinoa seeds as charred macroremains, make the plant one of the best represented and best studied cultigens in the Lake Titicaca region. Macrobotanical analysis has also shown that large quantities of wild seeds, dominated by grass and sedge species, were an important component of prehistoric samples. Their incorporation into the

[3] Wheat and barley are introduced Near Eastern crops, and are not discussed here.

archaeological record may be related to direct use or discard, or secondary deposition through the use of camelid dung as fuel (Whitehead 1999b; Wright *et al.* 2003).

Several varieties of wild and domesticated quinoa, as well as totora reed, an important local wild resource, were investigated for phytolith production (Table 4.1). All grass genera native to high elevation Bolivia (3000-4000 masl) were also investigated, and are reported in Chapter 6.

Table 4.1: Phytolith Production in Selected Local Utilized Plants

Scientific Name	Common Name	Part	Results
Chenopodium ambrosoides	Paiko	inflorescence	Lightly silicified spheres, not diagnostic
Chenopodium negra		inflorescence	Seed epidermal phytoliths, not diagnostic
Chenopodium negra		leaf	No diagnostic phytoliths
Chenopodium quinoa	Quinoa	inflorescence	Large cuboid non-silica bodies, not diagnostic
Chenopodium quinoa	Quinoa	stalk	No diagnostic phytoliths
Scirpus totora[4]	Totora	rhizome	No diagnostic phytoliths
Scirpus totora	Totora	seed	No diagnostic phytoliths
Scirpus totora	Totora	stem	Spheres with light projections, not diagnostic

Various parts from three species of *Chenopodium* were examined (*C. ambrosoides, C. negra, C. quinoa*), but none yielded any diagnostic phytoliths. Silica concentrations were quite small. Totora (*Scirpus totora* or *Schoenoplectus californicus*), however, was expected to yield abundant and diagnostic phytoliths, as had been documented in other members of the Cyperaceae (Ollendorf 1992). Surprisingly, no diagnostic phytoliths, and very little silica, was observed in seed, rhizome, or stem material. This is in contrast to silica observed in other *Scirpus* species. Ollendorf (1992) documented phytolith production in the Cyperaceae, and studied eight species of *Scirpus.* She found that this species produces diagnostic phytoliths in the seed epidermis. This discrepancy in phytolith production is perhaps related to the taxonomic affinity of totora,

[4] *Scirpus totora* has been renamed *Schoenoplectus californicus* (Bruhl 1995).

which has been placed in another genus, *Schoenoplectus* (Bruhl 1995). Because phytolith production is linked to taxonomy (*i.e.* species in the same genus should both silicify), totora being assigned to a different genus explains, in part, the lack of diagnostic phytoliths.

Other local plant families are more promising. Phytolith diagnostics have already been established for Asteraceae, Cyperaceae, and Fabaceae (Pearsall *et al.* 2006). Several wild grass species may also have been utilized, and are found commonly in the macrobotanical record (*e.g. Festuca* spp.); grasses are discussed in Chapter 6. Other families listed in Table 2.2 are less promising; for example Amaranthaceae, Cactaceae, Rosaceae, and Solanaceae typically do not silicify heavily or produce diagnostic phytoliths (Pearsall 2000; Piperno 2005). While many of these wild plants likely had food and utilitarian uses, it is difficult to separate these uses from environmental indicators that predominate in archaeological soil samples. This thesis does not focus on ecological indicators and these data will not be discussed here; refer to Appendix 2 for full results of soil and artifact scans. Therefore, although phytolith analysis is unable to address the role of quinoa, this plant is well-documented macrobotanically. With this in mind, the focus of microfossil analysis switched to the Andean tubers, which are underrepresented in plant macroremain assemblages.

ANDEAN TUBERS

It has long been suspected that the high elevation areas of the south central Andes are the homeland of domesticated tuber crops, including the potato, oca, and ullucu. This supposition derives from botanical studies of the distribution of the wild progenitors of these important crop plants (*i.e.* Harlan 1992; Vavilov 1926). Archaeological evidence for

these tuberous crops is limited to areas of extreme preservation, mainly on the arid Peruvian coast, in later time periods, or in overall small quantities (*e.g.* Ugent *et al.* 1982). Most of the evidence is in the form of charred or dried macrobotanical remains, and cannot be considered representative due to major preservation constraints on soft tissues. Given the important contribution of tubers to subsistence and agriculture today, it is imperative that new methods or approaches are used to address the development of this system. The objective of this section is to present results derived from the application of starch grain and phytolith analysis to the problem of tubers during the Formative period. First, the background and archaeological information currently available on these crops is presented. Results of analysis of comparative plant material to delimit diagnostic phytolith and starch forms, and the analysis of archaeological artifact residues are reported.

Background

The potato is the most well known of all Andean tubers, and the most successful Andean domesticate worldwide. Recently, development organizations have begun to recognize the value of other Andean tubers, like oca, ullucu, and mashwa (Arbizu and Tapia 1994; Flores *et al.* 2003; NRC 1989). These crops are often grown with potatoes in the high elevation Andes and fulfill similar starchy dietary requirements. However, subtle differences in agronomic properties, taste, and nutrition differentiate their roles in indigenous Andean agriculture and society. Unfortunately, a paucity of archaeobotanical evidence has prevented fine-grained analyses of the emergence and nature of these systems.

Potato (*Solanum tuberosum*: Solanaceae)

As a valuable economic crop, the potato has been the subject of much study. While most of these studies are on modern potato varieties, the tuber has also been recovered in archaeological contexts (Table 4.2). Currently, the potato is one of the most important crops worldwide, after wheat, maize, and rice. Several volumes (*e.g.* Hawkes 1990, Ochoa 1991) and the Centro Internacional de la Papa (www.cipotato.org) are the result of several years of ongoing research. Seven cultivated species and many more subspecies are recognized in the literature, but the primary one in the Andes is *Solanum tuberosum* subsp. *andigena* (Hawkes 1990).

The domestication of the potato is complex, especially considering the evolution of the species since its initial domestication. Hawkes (1990) suggests that the wild progenitor is *S. leptophytes*, which gave rise to the original domesticated potato, *S. stenotomum.* Both are found in northern Bolivia at high elevations and in the same phytogeographic region. *S. stenotomum* then hybridized with *S. sparsipilum* to form *S. tuberosum*, the domesticated species known today. Different selection pressures have produced hundreds of varieties. For instance, several frost resistant species have been bred by crossing *S. stenotomum* with local wild frost resistant species (*S. megistacrolobum* and *S. acaule*) in the highlands of northern Bolivia (Hawkes 1990).

The ability of the cultivated potato to hybridize with local wild species has increased the genetic diversity of the crop plant and enhanced its adaptability to regional climatic conditions (Hawkes 1990; Ladizinky 1998). Human selection for flavor, pest resistance, and other agronomic considerations has created much of this diversity, and increased the popularity of potato as a food crop in many different settings (Brush *et al.*

1995; Hastorf 1993). Five main cultivar groups of different ploidy levels are recognized taxonomically: groups *Tuberosum* and *Andigena* are tetraploid, *Chaucha* is triploid, and *Phureja* and *Stenotomum* are diploid (Ugent 1970:1163). The number of potato varieties in South America is enormous; in the region of Lake Titicaca alone the folk taxonomy of the Aymara recognizes over 200 varieties and subvarieties (La Barre 1947).

The potato is usually not consumed raw, but is boiled, baked, or an ingredient in stews. In the Andes it is often freeze dried to make *chuño*. The tubers may be frozen, thawed, and crushed. They are then dried to make *chuño*, or soaked in water and sun dried to yield *moray*. Flour can be made from *moray,* while *chuño* is stored and a common ingredient in stews (Towle 1961).

While the location and taxa involved in the domestication of the potato have been established though studies of modern species distribution and genetics, archaeological studies are needed to understand the nature and process of its domestication, and its role in prehistoric society. Potatoes are attested to archaeologically in two ways: through portrayal in artwork and as remains of the tuber itself. Ceramic vessels in the shape of various potato varieties have been found on the Peruvian coast, in Moche, Nazca, and Chimu sites (Hawkes 1990:13). Hawkes (1990) suggests that these vessels were rare, due in part to the fact that dry coastal Peru is not an ideal habit for potato cultivation. Whatever the case, it is difficult to establish the role of potatoes in coastal Peruvian diet based on the recovery of a few vessels depicting the gross morphology of potatoes.

Potato remains have been found on many archaeological sites through the Andes and coastal Peru and Chile. The oldest remains are from Monte Verde, where Ugent and others (1987) identified two skin fragments as *S. maglia*, a wild tuber-bearing taxon

native to the area. Specimens were uncharred and preserved by waterlogging, and date, by association, to 13000 BP (Ugent *et al.* 1987:17). The identification of the skin fragments was confirmed through starch grain analysis, as *S. maglia* produces a unique variety of grain shapes with specific size ranges not found in other *Solanum* species (Ugent *et al.* 1987). Ugent found desiccated domesticated potato in the coastal Peruvian sites of Pampa de las Llamas-Moxeke, Huaynuma, Tortugas, and Las Haldas, dating, by association, to 2000-1200 BC (Ugent *et al.* 1982:183). Ugent (*et al.* 1982) use surface morphology and starch grain analysis to identify the tubers, however no photographs or data are presented to verify the starch grain observations.

The remains identified by Ugent represent remarkable preservation situations encountered in waterlogged and desiccated environments. Few analysts have discovered identifiable potato remains in secure, early contexts. The earliest domesticated potato (*Solanum tuberosum*) comes from levels dating to 8000-6000 BC at the cave site of Tres Ventanas (Pearsall 1992), although direct AMS dating of a tuber from this context yielded a date of 5000 BC (Hawkes 1990; Pearsall in press).

Hastorf (1993) has identified potatoes in more common preservation situations, as carbonized macroremains. At Wanka sites in the Upper Mantaro Valley (Peru), potato remains increase over time, and even come to dominate the assemblage during Wanka II (at Tunanamarca)(Hastorf 1993). At Tiwanaku, potatoes form only a small portion of the archaeobotanical assemblage, but are concentrated in ritual areas (Wright *et al.* 2003). Kidder (1956 in Whitehead 1999) notes potato fragments at nearby Chiripa.

Both Hastorf (1993) and Wright (*et al.* 2003) attempt to ascertain the role of potatoes in ancient economies through quantification. This is made especially difficult

due to preservation constraints that apply to all tubers. The soft tissue of tuber storage bodies preserves much less readily than hard seeds, and is often rendered unidentifiable through charring distortion and fragmentation (Hastorf 1993; Pearsall 2000; Wright *et al.* 2003). Low preservation rates may also relate to uses and processing. Wright *et al.* (2003) suggest that a cuisine that focused on boiling of potatoes, rather than roasting, would contribute to overall low preservation of potatoes.

As discussed in Chapter 2, the only highland focused starch grain study published to date was conducted by Perry and colleagues (2006), who report the presence of small quantities of starch grains identified as cf. *Solanum* sp.. It was not possible to determine whether the grains represent a wild or domesticated taxon of *Solanum*, but the study does demonstrate use of at least a wild related species at the very least dating to 3600-4000 cal. BP.

Besides the potato, many other tubers are important in the Andean region. The focus here is on tubers originating in the Andes, rather than lowland tropical regions. Oca, ullucu, and mashwa are often grown in the same fields, as they are subject to the same conditions. They fare well in altitudes of 3000-4000 masl, but are most common at elevations of 3500-3800 masl. In short, the tubers are well adapted to the poor fertility regions and variable climate of the high Andes. As the tubers are often grown with native potatoes (Arbizu and Tapia 1994), it is to be expected that they are consumed by similar populations. Unfortunately, little is known about their role prehistorically, and how this might have changed since European contact, due to a paucity of archaeological evidence.

Oca (*Oxalis tuberosa* Molina: Oxalidaceae)

Oca is second only to the potato in importance to highland Andean communities. It is a staple in the high altitude regions of Bolivia and Peru. The tubers are ovoid to cylindrical, with rough to smooth skin and many buds, ranging in color from white and yellow to red and purple. The plant ranges from diploid to octoploid, and there is great variability in tuber color and morphology. The area of greatest diversity for both wild and domesticated forms is in central Peru and northern Bolivia, where domestication of the crop probably occurred (Arbizu and Tapia 1994; Flores *et al.* 2003).

Although modern varieties of oca can be consumed raw (NRC 1989), in the Andes it is often sun-dried, in order to increase sweetness, and then boiled, roasted, or roasted with meat in an earth oven (*pachamanca*) (Arbizu and Tapia 1994:149). The tuber may also be freeze-dried, like *chuño*, and if washed after freezing, it is considered better quality and ideal for making desserts (Arbizu and Tapia 1994).

There is little archaeological evidence for the use of oca in prehistory. The earliest date for oca (*Oxalis tuberosa*) is 8000-7500 BC from Guitarrero Cave (Pearsall 1992); but these remains may represent wild forms, and should be interpreted with caution. Yacovleff and Herrera (1934, in Towle 1961) report the depiction of oca in a Tiwanaku design from Pacheco, and also on a Chimu vessel. Towle (1961) found a small oca tuber in Inka levels at Pachacamac. Hastorf (1993) groups non-potato Andean tubers together for sites in the Upper Mantaro Valley, as they are present only in marginal amounts, and very difficult to distinguish from one another (see Table 4.2).

Ullucu or papalisa (*Ullucus tuberosus* Loz: Basellaceae)

Ullucu is widely distributed throughout the Andes, and is one of the most popular tubers throughout the region. The tubers are cylindrical to spherical, and come in colors of white, yellow, light green, pink, purple, and orange (Arbizu and Tapia 1994:160). Cultivated varieties are diploid or triploid. The area of ullucu domestication is unknown. It is prepared in soups and stews, and may be freeze-dried, as the other Andean tubers (Arbizu and Tapia 1994). The earliest evidence for ullucu is at Tres Ventanas, dating to 8000-6000 BC (Pearsall 1992). Towle (1961) reports archaeological occurrences at Ancon (Rochebrune 1879 in Towle 1961) and near Lima (Harms 1922 in Towle 1961), but few details are available (Table 4.2).

Mashwa (*Tropaeolum tuberosum* Ruíz & Pavón: Tropaeolaceae)

Although not as popular as the other tuber crops discussed, mashwa has the ability to grow on very poor soils in a shorter time, and produce yields greater than those of potato. The tubers are thought to have anti-aphrodisiac and medicinal properties. Mashwa is included in stews, or may be roasted or frozen overnight (*thayacha*) (Arbizu and Tapia 1994; Hastorf 1993; Towle 1961). Yacovleff and Herrera (1934, in Towle 1961) record the depiction of the entire mashwa plant in a Tiwanaku design from Pacheco (Table 4.2).

The importance of potato, oca, ullucu, and mashwa to modern populations is apparent, but their antiquity and role in prehistoric economies remains to be determined. Given the preservation constraints on macrobotanical remains, microfossil techniques are required to trace these tuberous plants archaeologically. The Taraco Peninsula is an ideal location to test for the presence of Andean tubers, as it is located in close proximity to the probable areas of domestication of these crops.

Table 4.2: Summary of Archaeological Evidence for Andean Tubers

Plant	Site	Date	Evidence	Source
Solanum maglia	Monte Verde	11000 BC (A)	Macro/Starch	Ugent *et al.* 1987
Solanum spp.	Ayacucho Waynuna	3100 BC (P) 1600-2000 BC (A)	Macro Starch	Pearsall 1992 Perry *et al.* 2006
Solanum tuberosum (potato)	Tres Ventanas Coastal Peru (several sites) Chiripa Tiwanaku Mantaro Valley	8000-6000 BC/5000 BC 1-800 AD (A) Late Formative? 500-1100 AD (A) Early Intermediate	Macro Macro/Starch Macro Macro Macro	Pearsall 1992, 2006 Ugent *et al.* 1982 Whitehead 1999b Wright *et al.* 2003 Hastorf 1993
Oxalis tuberosa (oca)	Guitarrero Cave Pacheco Pachacamac	8000-7500 BC (P?) 500-1100 AD (A) Inka (A)	Macro Depiction Macro	Pearsall 1992 Towle 1961 Towle 1961
Ullucus tuberosus (papalisa)	Tres Ventanas Ancon Chuquitanta	8000-6000 BC (P?) Preceramic? ?	Macro Macro Macro	Pearsall 1992 Towle 1961 Towle 1961
Tropaeolum tuberosum (mashwa)	Pacheco	500-1100 AD (A)	Depiction	Towle 1961

(A)= Associated date, (P)=Problematic date, Macro=Macroremains, Starch=Starch grains

Comparative Plant Studies

As few microfossil studies focus on Andean tubers, analysis of comparative plants was conducted to characterize the phytolith and starch grain assemblages of each species, and delimit potential diagnostics. Two groups of samples were processed and analyzed to document phytolith and starch production in Andean tubers. One set was completed by Alejandra Korstanje at UC Berkeley (Korstanje 2001), loaned to the University of Missouri Paleoethnobotany laboratory, and re-examined by A. Logan. The remaining material was collected in Bolivia, processed, and analyzed by A. Logan (Table 4.3).

In potato (*Solanum tuberosum*), there was little to no silica in the leaf, stem, tuber, or tuber skin; however, 'flower' shaped calcium oxalate druses were abundant in tuber skin (Figures 4.1 and 4.2). These druses seem to be distinctive; however, very little work has been done on using calcium oxalate crystals for archaeological purposes. This druse body

could be used as a secondary indicator, in conjunction with other data sources like starch grains, to identify potatoes, but cannot be used as a diagnostic at this time.

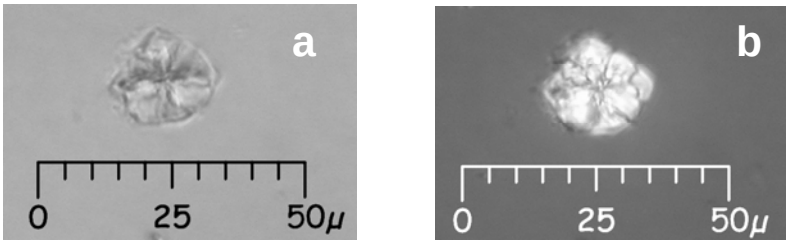


Figure 4.1: Flower sphere , Comparative *S .tuberosum*
a) Transmitted light (N1305); b) Polarized light (N1306)

Table 4.3: Andean root and tuber comparative specimens

Scientific Name	Plant Part	Phytoliths	Starch grain	Calcium oxalate
Solanum tuberosum	Leaf*	None	--	--
	Stem*	None	--	--
	Tuber*	None	Yes	--
	Tuber skin	None	Yes	Flower sphere
Oxalis tuberosa	Leaf*	Yes, not diagnostic	--	--
	Stem*	None	--	--
	Flower*	None	--	--
	Tuber*	Yes, not diagnostic	Yes	--
	Tuber skin	None	Yes	--
Ullucus tuberosum	Leaf*	None	--	--
	Flower*	None	--	--
	Tuber*	Yes, not diagnostic	Yes	--
	Tuber skin	Yes, not diagnostic	Yes	--
Tropaeolum tuberosum	Leaf*	None	--	--
	Stem*	None	--	--
	Root*	None	--	--
	Tuber*	None	Not tested	Not diagnostic
Lepidium meyenii	Leaf*	None	--	--
	Root*	None	Not tested	Not diagnostic

*Originally processed and analyzed by A. Korstanje (2001), reanalyzed by A. Logan

None of the plant parts tested of oca (*Oxalis tuberosa*) contained identifiable silica. No identifiable phytoliths were visible in papalisa (*Ullucus tuberosus*). Less work was focused on maca (a crucifer) and mashwa, as they are not heavily used today; however, no diagnostic silica was present in the plant parts tested. The remainder of this chapter instead focuses on potato, oca, and ullucu.

The overall disappointing results of phytolith comparative work suggested that instead, starch grains may be a more appropriate means of tracking the Andean tubers. Starch grains were examined from eight different varieties of potato, two varieties of oca, and two forms of papa lisa (Table 4.4).

Table 4.4: Local tuber varieties examined for starch grains

Field No.	Scientific Name	Local Name[5]/Description
1 (54)	*Solanum tuberosum*	janqu chuqi, papa blanca
2 (55)	*Solanum tuberosum*	ch'iyaramilla
3 (56)	*Solanum tuberosum*	chi'yar surimana
4 (57)	*Solanum tuberosum*	allqa surimana
5 (58)	*Solanum tuberosum*	ch'iyara imilla, papa negra
6 (59)	*Solanum tuberosum*	wila surimana
7 (60)	*Solanum tuberosum*	papa phurixa
8 (61)	*Oxalis tuberosa*	Red
9 (62)	*Oxalis tuberosa*	Yellow
10 (63)	*Ullucus tuberosus*	Red
11 (64)	*Ullucus tuberosus*	Speckled

While overall morpholology of starch grains in the Andean tubers is quite similar, there are a few distinguishing factors, which, with more research, may serve to separate these important species (Figure 4.2, Table 4.5). First, while extinction cross appearance varies considerably within each species, there are general differences that may serve to separate each taxon. In addition, ullucu starch grains are generally smaller than those of potato or oca. While the general shape of potato and ullucu grains overlap, oca grains are distinctly clam shell shaped. All species are similar in regards to angularity, although the bottom of potato grains is sometimes flattened. Lamellae are also more pronounced in potato. Fissure patterning on oca and ullucu is similar; in potato starch fissures are far less common and usually radiate from the hilum. A smooth surface, lack of protuberances, double outer wall, and lack of compound grains are characteristics shared

[5] Local Aymara and Spanish names were gathered by M.C.Bruno. Any spelling and/or orthography mistakes are my own.

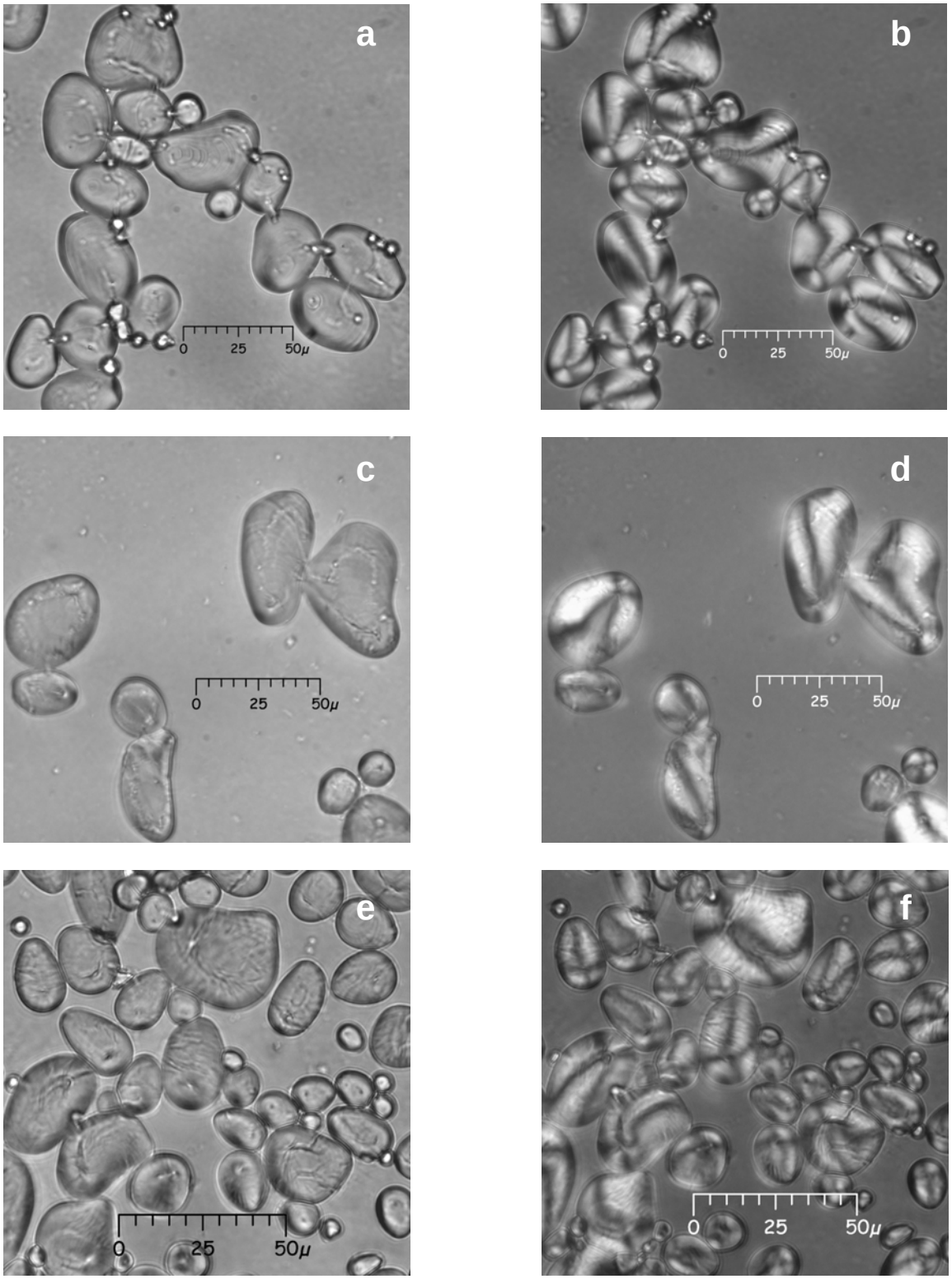


Figure 4.2: Starch grains from modern comparative tuber samples.
Solanum tuberosum a)Transmitted light (N1327), and b) Polarized light (N1328); *Oxalis tuberosa* c) Transmitted light (N1191), and d) Polarized light (N1190); *Ullucus tuberosus* e) Transmitted light (N1333), and f) Polarized light (N1334)

by all three taxa examined. No major differences were observed between different varieties of the same species.

Table 4.5: Andean Tuber Starch Grain Morphology

Attribute	*Solanum tuberosum*	*Oxalis tuberosa*	*Ullucus tuberosus*
Extinction cross	Other angle (not 90º), narrow arms	Other angle, sharper, narrow arms	Other angle, bent narrow arms
Granule Size	78x50 to 28x15 μ	75x33 to 15x13 μ	45x23 to 13x8 μ
Granule Shape	Spherical to ovate	Clam shell shape	Ovate
Angularity	Round, bottom may be flat	Round	Round
Lamellae	Coarse	Fine	Fine
Hilum	Open	Open	Open
Fissures	Radiating (rare)	Y or linear common	Linear or Y common
Surface	Smooth	Smooth	Smooth
Protuberances	None	None	None
Outer Wall	Double	Double	Double
Compound	N/A	N/A	N/A

ARCHAEOLOGICAL RESULTS—STARCH RESIDUES

The focus of the archaeological portion of this study was on starch grains from artifact residues, as methods for isolating starch grains directly from soil samples (*i.e.* Perry *et al.* 2006) were still in development at the outset of this project. Starch grains from artifacts can be directly associated with a particular artifact, and lead to information about its function, providing a strong correlation with human use. Artifact residue analysis focused on samples collected in the 2004 and 2005 field season, which included selected objects from previous excavations at Chiripa (1992-1999, 2004), Kala Uyni (2003, 2005), Sonaje (2004-2005) and Kumi Kipa (2004). Priority was given to artifacts in good Formative period contexts, but some artifacts were sampled from Tiwanaku contexts for comparison. Several different classes of artifacts were tested in order to figure out which types were more productive and useful for answering the research questions. An example of each artifact class sampled is pictured in Appendix 2B.

Results were quite variable. In total, 63 samples were processed, accounting for 27 artifacts (Appendix 2A). The focus was on Sediments 2 and 3, as Sediment 1 represents surrounding soil, and cannot be directly related to artifact use. Sediment 2 (wet brush) often contains the majority of phytoliths from artifact use. Sediment 3 (sonicated) typically contains most of the starch residues (*e.g.* Pearsall *et al.* 2004). The first priority was to examine starch residues in order to trace the Andean tubers; phytolith data will be reviewed in the next two chapters. In total, 31 starch slides were completed. Overall, starch was rare, and manos were the most productive artifact type for residues. A full list of artifacts, results, and context information is presented in Appendix 2A.

Stone Tools

Manos were the most productive artifact class. Eight have been processed and analyzed. Maize starch grains were found on 2 manos, both from Chiripa-Quispe (Locus 3114, 3132; see Ch. 6). One other Chiripa-Quispe mano had possible maize starch (Locus 3109). One metate fragment was sampled and processed, but no diagnostic starch was encountered. Additional evidence for maize on Chiripa manos was found using phytolith analysis; results are reported in Chapter 6. One large stone hoe from Sonaje was also tested; no starch grains were obtained, and one cf. Cyperaceae phytolith was identified. Two slate knife fragments from Chiripa were analyzed, but only one small, unidentified starch grain was recovered (Locus 565). Finally, one stone trompo from Sonaje was processed, but had no starch residue.

Bone and Bone Tools

Teeth from four human mandibles have been processed and analyzed[6]. Two unidentified starch grains were recovered on teeth from Kala Uyni (Locus 5316). Teeth from Kala Uyni (Locus 5268) yielded one maize starch grain, as well as phytoliths from *Scirpus* sp. and possibly maize ruffle-top rondels. Bone tools were also sampled. Two llama mandible scrapers and one scapula comb were analyzed. The use surface (*i.e.* the distal end) of the llama mandible tools were sampled (Figure 4.3c), following the advice of project zooarchaeologist Dr. K.M. Moore, not the teeth, as the focus was human activities rather than camelid diet. Surprisingly, one large ovate starch grain, possibly from a tuber, was recovered from a llama mandible scraper (Sonaje, Locus 6048) (Figure 4.3). While it appears damaged, the grain does have the overall shape and fissure pattern of Andean tuber starch. However, it is lacking lamellae, has an obscured extinction cross, and appears flattened. These characteristics are common in potato starch grains that have been freeze-dried (Babot 2003), and may extend to other Andean tubers as well.

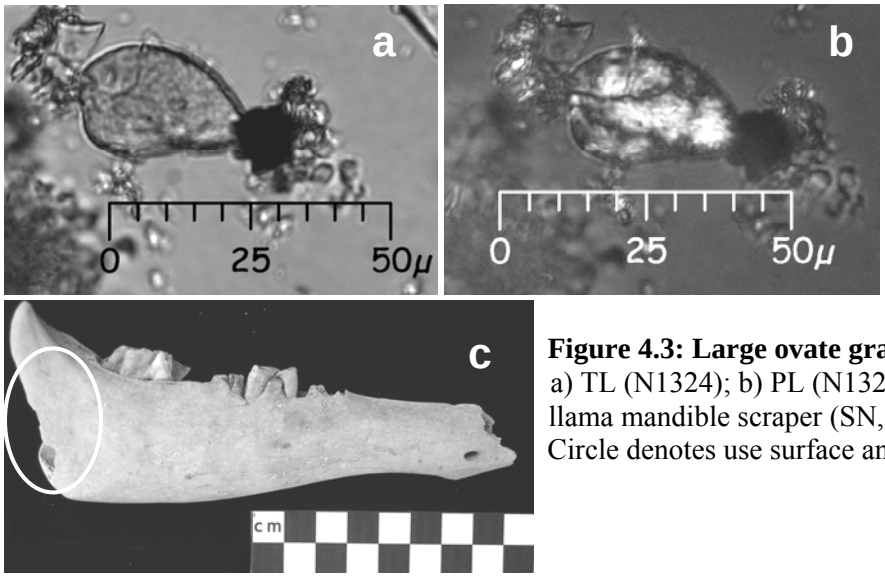


Figure 4.3: Large ovate grain from SS 390
a) TL (N1324); b) PL (N1322) recovered on llama mandible scraper (SN, Locus 6048)
Circle denotes use surface and area sampled

[6] Unlike many previous studies, the dental calculus was not sampled, as there was little if none visible on human teeth. Instead, the teeth were sampled like artifacts, as described on page 33.

Ceramics

Three ceramic trumpet fragments were processed, but contained no starch grains or identifiable phytoliths. Two whole ceramic pots were analyzed. A Tiwanaku *incensario* contained no starch grains, but a Tiwanaku 1 pot did have one grain diagnostic of maize, and both vessels contained diagnostic maize phytoliths (see Ch. 6).

Two "crucibles" were also sampled, but contained no identifiable starch.

Despite the overall negative results of the search for Andean tubers, the evidence is in line with both macroremain evidence and other highland microfossil studies. Some general trends are important. First, most of these artifact types are not productive for starch residues. Manos, metates, hoes, ceramic vessels, and trumpet fragments are worth pursuing more, but the other artifact classes are not productive. Second, surprisingly no tuber starch was found on any of these tools, except possibly a llama mandible scraper. A possible explanation is that none of these artifacts came into contact with tubers (*i.e.* manos usually are used to grind seeds, not potatoes). Preservation constraints and damage to grains may also be affecting recovery, or perhaps tubers were not used in this time period or at these sites. Finally, there is a considerable amount of unidentified starch, ranging from very small grains to large ovate grains, which require more comparative work for identification.

CHAPTER SUMMARY

Despite the importance of Andean crops native to the highland region, archaeological evidence of the timing and nature of their use remains elusive. While preservation is optimal for seed crops like quinoa, Andean tubers are underrepresented in the macrobotanical record. Microfossil analysis was explored as a potential avenue for

tracking Andean tubers and some local plants, but unfortunately, phytolith production was insignificant in all plants tested. Starch grain analysis was employed as an alternative, since tuberous plant parts form large quantities of starch. Unfortunately, analysis of starch grains from artifact residues yielded very little evidence of Andean tubers, with the exception of a single probable grain.

CHAPTER 5
HALLUCINOGENIC AND EXOTIC PLANTS ON THE TARACO PENINSULA

INTRODUCTION

Exotic plants have long been a part of ritual and domestic life in the Andean highlands. The positioning of the Andean region, with the Amazonian rainforest to the east, and the coastal Peruvian desert to the west, means not only that Andean peoples had access to products of those ecotones, but to goods, ideas, and people passing between them. The excellent preservation of archaeological materials on the dry Peruvian coast has allowed for the recovery of lowland plant resources, including roots and tubers and possibly hallucinogens since at least the Initial period. However, as discussed previously, few hallucinogenic or exotic plants (besides maize) have been recovered in archaeological contexts in highland Bolivia, especially during the Formative period.

Comparative plant specimens were documented for phytolith and calcium oxalate crystal production, in order to develop diagnostic indicators for hallucinogens of interest. Residues from a number of artifacts, with purported ritual and domestic functions, were studied to test for the presence of hallucinogens and other lowland plants. Archaeological soil samples were also analyzed from both ritual and domestic sectors.

HALLUCINOGENIC PLANTS

Hallucinogen use in prehispanic South America is well known by the Late Horizon. Archaeologically, presence of hallucinogens is typically demonstrated by implements used in their preparation or ingestion (Torres 1995), pottery or art motifs displaying their use (Burger 1992), or macrobotanical remains (Hastorf 1987; Torres

1995). Many of these techniques establish the presence of hallucinogens indirectly; others, such as macrobotanical remains, are scarce and subject to many preservation constraints; finally, most artifacts can be used to prepare a number of different hallucinogens, making it difficult to identify which hallucinogens were used (and why).

Currently there is scant evidence of hallucinogen use during the Formative period on the Taraco Peninsula. However, establishing the presence or absence of hallucinogenic plants and their use contexts is important for understanding the growth of ritual in the region. Considering the constraints above, phytolith analysis was employed in order to track individual hallucinogenic plants in the archaeological record.

Background

A plethora of information regarding modern and historical hallucinogen use in South America is available, showing the diversity of uses for a variety of chemically active plant genera and families (*e.g.* Schultes and Hofman 1979). Such studies are helpful in that they direct archaeologists to the likely contexts where hallucinogens were used, as well as the plant parts utilized. This is especially important for the purposes of phytolith analysis, which requires testing of the appropriate plant parts for diagnostic forms, as well as targeting the appropriate artifacts and locations where they may have been used. A list of important hallucinogens was compiled based on Schultes and Hofmann (1979), deFeo (2003), de Smet (1985), Torres (1995), and Hastorf (pers. comm. 2004). Basic information about uses, taxonomy, and archaeological evidence for 12 hallucinogens of interest is reviewed in Table 5.1.

Table 5.1: Major South American Hallucinogens, their uses, and archaeological evidence

Scientific Name	Family	Common Name	Use/Form	Parts Used	Archaeological Evidence
Anadenanthera colubrina	Fabaceae	Vilca	Snuff for divination, healing, stimulant, trance Smoked	Seeds Leaf	Snuff trays common in later periods Oldest evidence at Inca Cueva, Argentina at 2130 BC (seeds)
Banisteriopsis spp., *B. caapi*	Malpighiaceae	Ayahuasca	Psychoactive drink for divination, sorcery, medicine Additive to other hallucinogens	Bark Leaf	No conclusive evidence
Brugmansia spp., B. aurea	Solanaceae	Floripondio	Infusion Additive to fermented drinks Smoked	Leaf, bark, flower Leaf	No conclusive evidence
Datura spp.	Solanaceae	Jimsonweed	Additive to beverages	Seeds, Leaf, Root	No conclusive evidence
Erythroxylum coca	Erythroxylaceae	Coca	Chewed, Infusion, Smoked Snuff	Leaf	Depicted in figurines 2100 BC Macroremains in Late Horizon, Upper Mantaro Valley (Hastorf 1987)
Ilex vomitoria, I. guayasa	Aquifoliaceae	Mate	Ritual stimulant and/or emetic	Leaf	Leaves in highland Bolivian tomb (Tiwanaku 4/5 period)
Nicotiana tobaccum, N. paniculata, N.rustica, N. sylvestris, N. glauca	Solanaceae	Tobacco	Snuff, Smoked, Consumed, Taken rectally	Leaf, Root	*Nicotiana* sp. seeds at Chiripa—may be wild non-useful species (M.C. Bruno pers. comm. 2006)
Opuntia cylindrica, O. leptocalis	Cactaceae	?	Information limited	Stem	No conclusive evidence
Psychotria viridis	Rubiaceae	?	Information limited	?	No conclusive evidence
Trichocereus pachanoi, T. peruvianus	Cactaceae	San Pedro Cactus	Hallucinogenic intoxicant used for divination and disease diagnosis	Stem	Earliest evidence is depiction at Chavin dated to 1300 BC
Virola spp.	Myristicaceae		Snuff, Swallowed, Smoked	Bark	No conclusive evidence

*Compiled based on Schultes and Hofman (1979), Torres (1995), deSmet (1985), deFeo (2003), Hastorf (1987), Plowman (1984), Wassen (1972)

While Table 5.1 only provides a brief summary about each hallucinogen taxon, it does sketch out relevant starting points for the purposes of microfossil analysis, including which plant parts to sample and taxonomic affinity. Considerable information is also available concerning the uses and effects of each plant. That information will not be reviewed here, but is easily accessible in Schultes and Hofman (1979).

One other important factor in tracking hallucinogenic plants archaeologically is contextual in nature. While one would expect to target ritual areas, in some places, including the Taraco Peninsula, ritual seems to be a part of domestic life as well (Dean and Kojan 1999). Therefore it is preferable to sample a large range of contexts. The second contextual issue relevant for the present analysis is what objects might be used in the processing and/or consumption of psychoactive plants. Residue from equivalent or similar artifacts may be very promising.

Objects used in the preparation of hallucinogenic snuffs include implements used for grinding (mano, metate), trays, and tubes. Other forms of preparation, such as for infusions or additives to beverages, may also involve grinding. Hallucinogenic drinks may have been consumed in some sort of cup, and may have been prepared in a larger ceramic vessel. Archaeologically, many of these implements should preserve if constructed of ceramic or stone. Analysis of the residue on these artifact forms may be one of the most productive ways of tracing prehistoric hallucinogen use.

Comparative Plants

Phytolith production in hallucinogenic plants that may have been used in highland Bolivia was documented for a number of genera. All plants, with the exception of vilca (*Anadenanthera colubrina)* and coca (*Erythroxylum coca*), were obtained from the

Missouri Botanical Garden. All hallucinogens were processed using the dry ashing technique (Pearsall 2000).

Phytolith and calcium oxalate crystal production was documented in 12 hallucinogens, including the plant parts used as well as leaf samples, when available. A total of 25 samples were examined (See Appendix 3A for detailed results; Tables 5.2 and 5.3 below). As most of the hallucinogens are from tropical regions, it was expected that phytolith forms produced would stand out from the local, temperate assemblage. However, several of the plant families represented, including Solanaceae and Rubiaceae, have been studied extensively and do not produce diagnostic phytoliths (Pearsall 2000; Piperno 2005).

Table 5.2: Hallucinogenic plants with no diagnostic silica

Scientific Name	Common Name	Family	Parts tested
Brugmansia aurea	Floripondio	Solanaceae	Bark, flower, seed, leaf
Erythroxylum coca	Coca	Erythroxylaceae	Leaf (2), seed
Ilex retusa	Mate?	Aquifoliaceae	Leaf
Nicotiana spp. (2)	Tobacco	Solanaceae	Leaf, root
Opuntia cylindrica	--	Cactaceae	Stem
Psychotria viridis	Chacruna	Rubiaceae	Fruit, leaf
Trichocereus sp.	San Pedro cactus	Cactaceae	Stem
Virola spp. (2)	--	Myristaceae	Bark, inner bark, leaf, pod, seed

Table 5.3: Hallucinogenic plants with diagnostic phytoliths

Scientific Name	Common Name	Family	Parts tested
Anadenanthera colubrina	Vilca	Fabaceae	Seed, pod*
Banisteriopsis caapi	Ayahuasca	Malpighiaceae	Bark, leaf*
Datura inoxia	Jimsonweed	Solanaceae	Seed, leaf*

*Plant parts that contained diagnostic forms

Both the seed and pod of *Anadenanthera colubrina* were analyzed for phytolith production by A. Korstanje (2001) and for the present study[7]. While the seed was unproductive, the pod contained two possible diagnostic phytolith types.

***Anadenanthera colubrina* (pod) Type 1**: Non-quadrilateral epidermal phytolith, granular surface with rounded central projections. Potentially useful (Figure 5.1).

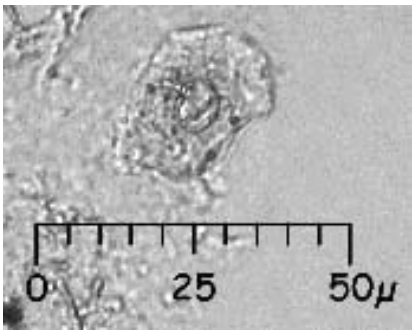


Figure 5.1: Type 1 (N953)

***Anadenanthera colubrina* (pod) Type 2**: Polyhedral phytolith with central depression, heavily silicified, two tubular sides with 'stripes'. Diagnostic (Figure 5.2).

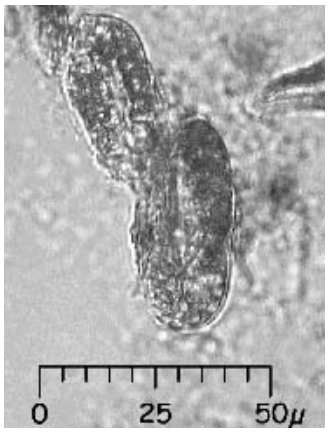


Figure 5.2: Type 2 (N956)

Type 1 is perhaps too generalized and redundant; many plants, especially in the Cyperaceae, produce non-quadrilateral epidermal phytoliths. More investigation within this genus may help narrow down a unique epidermal form. Type 2 however is very

[7] Specimens of *Anadenanthera colubrina* were processed and originally analyzed by A. Korstanje. I looked at slides on loan from her collection, with similar results.

promising, as it appears to be unique to at least this genus, and will be considered a diagnostic for TAP samples.

Comparative specimens of bark from *Banisteriopsis* sp., and the bark and leaf of *Banisteriopsis caapi* were examined for phytolith production. The bark samples exhibited low silica concentrations overall and yielded no diagnostic phytoliths. Calcium oxalate druses were very abundant, but unfortunately are found across many families. However, potentially diagnostic phytoliths were isolated from the leaf.

***Banisteriopsis caapi* (leaf) Type 1**: large, blocky epidermal phytoliths. Possibly diagnostic (Figure 5.3).

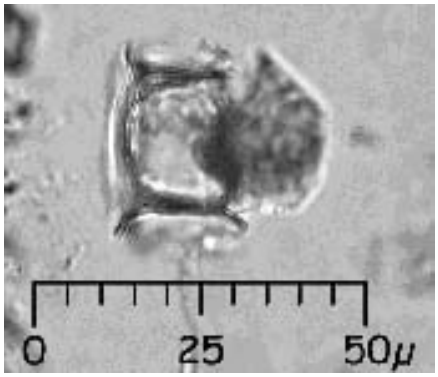


Figure 5.3: Type 1 (N1346)

***Banisteriopsis caapi* (leaf) Type 2**: Hair cell base. Possibly diagnostic (Figure 5.4).

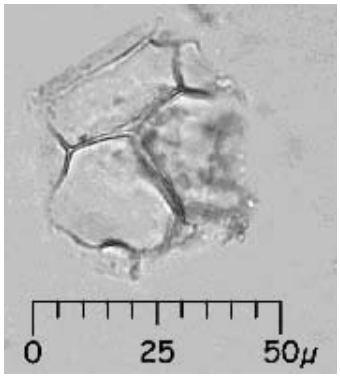


Figure 5.4: Type 2 (N1349)

***Banisteriopsis caapi* (leaf) Type 3**: Three dimensional triangular tent-like body, anatomical origin unknown. Possibly diagnostic (Figure 5.5).

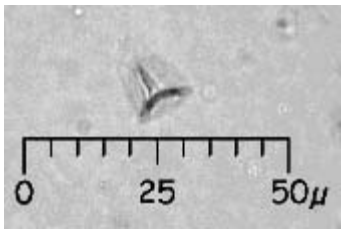


Figure 5.5: Type 3 (N1350)

Type 1, a large blocky epidermal phytolith, can possibly be used as a diagnostic, as no other local plants are known to produce this form. Type 2, a hair cell base, is also promising as it is unique to this specimen. Type 3 is more of an oddity; it may be useful as an indicator of *Banisteriopsis*, but more research is needed. In all cases, the Malpighiaceae should be more fully examined for phytolith production and possible confusers.

The bark, flower, seed, and leaf of *Brugmansia aurea* were tested for phytolith production. The bark, flower, and seed produced no diagnostic phytoliths. The leaf, however, contained large, multicellular hairs, which may be a possibly useful phytolith type. Since multicellular hairs are produced in a number of plant families, this type will have to be more closely compared to other taxa.

***Brugmansia aurea* (leaf) Type 1**: Large multicellular hair, thin with double outline. Diagnostic value limited, may be redundant (Figure 5.6).

Figure 5.6: Type 1 (N1347)

Both seed and leaf samples of *Datura inoxia* were analyzed. No diagnostic phytoliths were discovered in the seed sample, but phytoliths in the leaf are very promising.

***Datura inoxia* (leaf) Type 1**: Hair cell base, squarish to round with double outline and central projection, parallel ribs extending from axis. Possibly diagnostic (Figure 5.7).

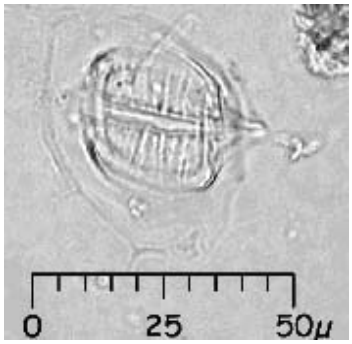


Figure 5.7: Type 1 (N1343)

Currently, this hair cell base is unique and can be used as a diagnostic. This is somewhat surprising, since the Solanaceae typically do not produce diagnostic silica bodies (Pearsall 2000; Piperno 1988).

Documenting phytolith and calcium oxalate production in coca has proved to be a particular challenge. A leaf specimen processed by Korstanje (2001) was examined in early 2004, and pieces of tissue with rod-like inclusions were documented in moderate amounts. As this particular form had not been observed in any slide of the MU Phytolith comparative collection, it was originally considered a possible diagnostic. Additional coca leaf material collected by C. Hastorf in Bolivia was processed and analyzed, with similar results. However, during this same period the MU Paleoethnobotany lab returned to the dry ashing method of comparative plant extraction. Tissue with rod inclusions was noted in several unrelated taxa that had been ashed. This body, which is composed of calcium carbonate and/or calcium oxalate, is normally destroyed as part of chemical

comparative processing techniques, but is preserved through ashing. Therefore, it should be considered redundant and cannot be used to identify coca. Unfortunately, there are no diagnostic phytoliths or calcium oxalate crystals in leaf or seed material.

A leaf specimen of *Ilex retusa* was examined, and no diagnostic phytoliths or calcium oxalate bodies were observed. Leaf and root material of *Nicotiana rustica* was examined, as well as leaf material of *N. tobaccum.* Multicellular hairs and smooth spheres are produced in leaf material (Appendix 3A). No diagnostics were delimited for this genus. The flesh (stem) of *Opuntia cylindrica* was examined for phytolith and calcium oxalate production, but produced no diagnostic forms. The calcium oxalate bodies may be of some limited use with more comparative work on calcium oxalate production in Cactaceae.

Both fruit and leaf material of *Psychotria viridis* were tested. The fruit produced no distinctive phytolith forms. Silicified, scalloped tissue located in the leaf may be of some limited value, but is not diagnostic (Appendix 3A). The flesh/stem of *Trichocereus cuzcoensis* produced no diagnostic calcium oxalate or silica forms. The bark of *Virola nobilis*, and the bark, inner bark, leaf, pod, and seed of *V. peruviana* were assessed for phytolith production, but all were characterized by relatively low silica concentrations, and no diagnostic phytoliths.

In sum, while the results from the comparative study negate recovery of many important hallucinogens, such as coca, possibly diagnostic phytoliths are found in *Anadenanthera colubrina, Banisteriopsis caapi, Datura inoxia,* and perhaps *Brugmansia aurea.*

EXOTIC PLANTS

Hallucinogens are not the only non-local plants that may have been traded into the Taraco Peninsula. Exotic plants, primarily from lowland tropical regions, are found in coastal Peruvian contexts, and in some highland Andean locales (*e.g.* Perry *et al.* 2006). Fortunately, phytolith production in lowland tropical plants is extremely well-documented compared with other regions, as it has been a focus of research since the 1970s (*i.e.* Pearsall 1979, 2000; Piperno 1988, 2005). As the University of Missouri Paleoethnobotany laboratory specializes in the identification of lowland plants, diagnostics for scores of tropical plant families are documented and readily available. Diagnostics will not be reviewed here, as they are available elsewhere (*e.g.* Pearsall 2000; Pearsall *et al.* 2006; Piperno 2005).

ARCHAEOLOGICAL RESULTS

Both artifact residue and soil samples were examined for hallucinogenic and exotic plants. Artifacts may be the most appropriate provenance for plants that were rarely used or only in small quantities, such as hallucinogenic or trade plants. The signature of these plants may be so faint as to be overlooked in the analysis of soil samples. In addition, it may be possible to address functions of certain unknown use artifacts, especially those with a purported role in ritual, based on the types of plant residue present. For these reasons, a wide variety of artifact types were sampled, as described in Chapter 4. Soil samples were also examined for hallucinogenic and exotic plants, as they provide a broader spectrum in which to locate these rare and elusive plants.

Phytolith Residues from Artifacts

Artifact classes sampled included manos, metate fragments, stone hoes, slate knife fragments, human mandibles, bone tools, ceramic trumpet fragments, and whole ceramic vessels (Appendix 2B). Both Sediment 2 and 3 fractions from 27 artifacts total were examined from 4 sites (Chiripa, Kumi Kipa, Sonaje, and Kala Uyni), totaling 63 samples. Full results can be found in Appendix 2A. It was expected that artifacts associated with ritual contexts (*i.e.* ceramic trumpets), and sites with sizeable ritual sectors (Chiripa and Kala Uyni) would be the most productive for tracking hallucinogenic plants. However, given that ritual offerings have also been found in domestic contexts at Chiripa (Dean and Kojan 1999), a wide range of artifacts and soil samples were examined.

Artifact types that may have come into contact with hallucinogens included ceramic trumpets, manos, crucibles, bone tools, and slate knives (see photos in Appendix 2B). Ceramic trumpets are thought to have a role in ritual/ceremonial practice in the study region (Chávez 1988). Since many hallucinogenic parts (*i.e. Anandenanthera* seeds) must be ground, manos were also thought to have potential. In addition, unknown use artifacts (crucibles, llama mandible scrapers, scapula combs, and slate knives) may have had a role in the preparation or consumption of psychoactive plants.

Unfortunately, no trace of hallucinogenic plants was found on any artifact. Reasons for this negative result are considered in the discussion. However, this study has outlined diagnostic phytolith forms in three common hallucinogens of South America that may be applied throughout the Andes.

Comparatively more diagnostic forms exist for tropical lowland plants. All artifact residues were examined for lowland species. Several indicators of tropical plants were

uncovered, including a palm (Arecaceae) sphere (Figure 5.8a) and nodular spheres (Figures 5.8b,c) that represent Marantaceae, Bombaceae, and/or Zingiberaceae[8]. The palm sphere occurred in a Tiwanaku 1 pot (MU 2360, Locus 6782) from Kumi Kipa, but because spheres are produced in several plant parts (leaf, fruit, etc.) (Piperno 2005), this could essentially mean any number of things—palm fruits may have been part of the pot contents, or a stray palm leaf fragment was incorporated from an unrelated activity, among many other possibilities. In any case the faint signature suggests use of any palms was limited.

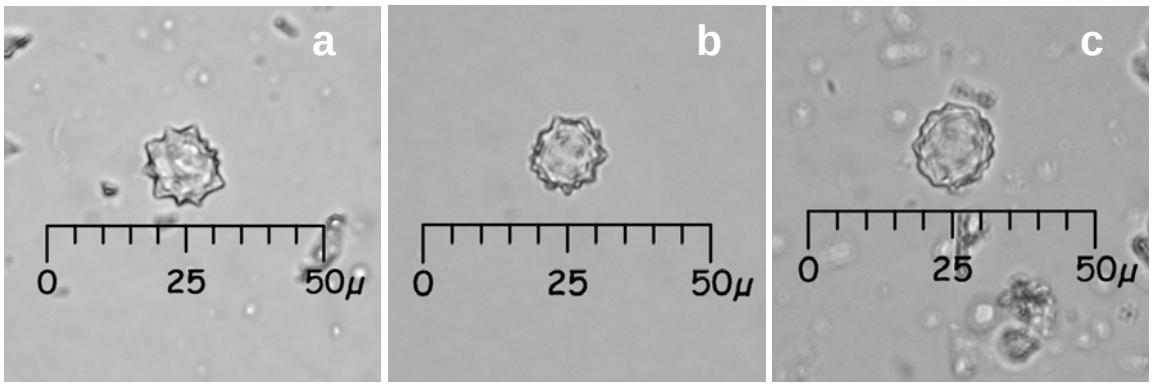


Figure 5.8: Selected spheres in TAP samples
a) Spinulose sphere, Arecaceae, MU 2360 (N1448); b) Nodular sphere, Possibly Marantaceae, MU 2304 (N1450); c) Nodular sphere, Possibly Marantaceae, MU 2309 (N1452)

The nodular spheres come from manos, one probably belongs to the Tiwanaku 4/5 period (MU 2304, Locus 6561, Site KK), but the other was found at Chiripa Quispe (MU 2309, Locus 3132), and falls within the Formative period. Singular nodular spheres were also found on human teeth (MU 2306, Locus 5282, Site KU), a scapula 'comb' (MU 2311, Locus 6080, Site SN), and the same Tiwanaku 1 ceramic vessel that contained the palm sphere (MU 2360, Locus 6782, Site KK). The presence of nodular spheres on

[8] Nodular spheres were a type established early on in the history of phytolith analysis that was thought to be diagnostic to the family Marantaceae. The type is currently undergoing review at the MU Paleoethnobotany Laboratory. Here the conservative identification is reported.

several different artifact types, at various sites, and over various time periods, suggests that there may be a more robust pattern than that observed for the palm sphere.

Phytoliths in Soil Samples

Analysis of soil samples concentrated primarily on contexts from Kala Uyni. Full results are communicated in Appendices 2C-F. This site contains a significant ritual/ceremonial component atop a hill, surrounded by a series of unknown function structures at the base, and possibly a sizeable domestic component (Bandy *et al.* 2004). In addition, Kala Uyni is one of the largest settlements on the Taraco Peninsula during the Late Formative period (Bandy 2004), making this an ideal site to test for hallucinogenic and exotic materials that would have been procured through trade networks.

In total, 20 soil samples from Kala Uyni were analyzed from the sunken court, middens surrounding the court, and unknown use structures and middens at the base of the hill. Overall phytolith assemblages were richest and most dense from midden formations. However, results were similar to that of the artifact residue analysis. No evidence whatsoever of hallucinogens was found.

However, there were a few several exotic indicators, including one nodular sphere representative of Marantaceae, Zingiberaceae, or Bombaceae (KU, Locus 5154). While an identification of Marantaceae makes the most sense, given findings of arrowroot at a highland Peruvian site of this period (Perry *et al.* 2006), no secure indicators of this species were uncovered. This is despite the fact that Marantaceae produces a large number of phytolith diagnostics (Pearsall *et al.* 2006).

Interestingly, a wide variety of unknown phytoliths were present in TAP samples. Most important of these are a variety of different hair cell bases, which are currently

unidentified. However, hair cell bases are typically diagnostic to some level, are indicative of dicotyledons, and may represent tropical taxa. One hair cell base (Figure 5.9b) has been tentatively identified as *Cordia lutea* (AQ, Locus 5082), while another is similar to forms encountered in the Boraginaceae family (AC, Locus 5112) (Figure 5.9c). However, more extensive comparative work is needed on plants of the eastern slops of the Andes, as well as the Amazon, before firm identifications can be derived.

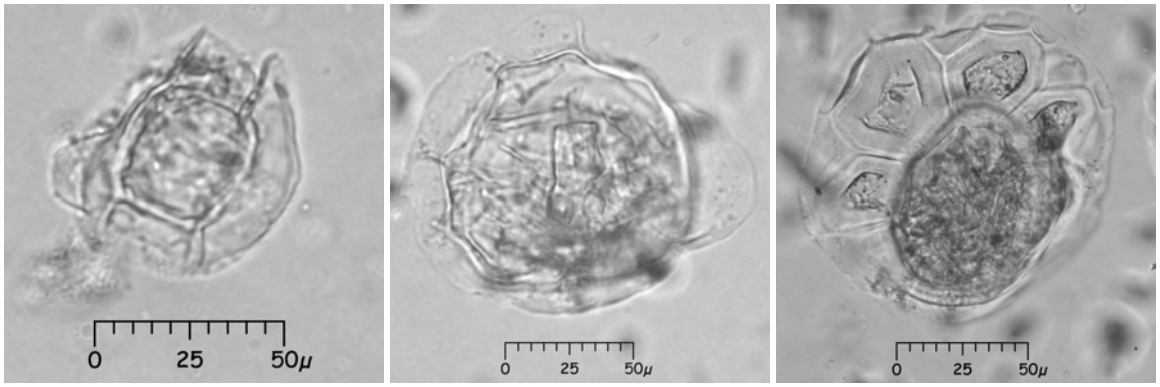


Figure 5.9: Selected hair cell bases in TAP samples
a) Unidentified, MU 2206, AC Locus 5018 (N1132); b) cf. *Cordia lutea*, MU 2192c (N1141); c) Possible Boraginaceae, MU 2246 (N1172)

CHAPTER SUMMARY

The role of hallucinogenic and exotic plants in the development of complex social networks in and beyond the Titicaca basin was explored through phytolith analysis of artifact residue and soil samples. Comparative plant work on the major hallucinogens of South America delimited diagnostic phytoliths in three species, vilca, ayahuasca, and jimsonweed. Unfortunately, no evidence of hallucinogen use was uncovered on artifacts or in soils. Scores of phytolith diagnostics exist for plants of the tropical lowlands of South America, thanks to the strong focus of microfossil work conducted in those regions. Tropical indicators, including a palm sphere and nodular spheres, were discovered in artifact and soil samples.

CHAPTER 6
IDENTIFYING MAIZE IN THE ANDEAN HIGHLANDS

INTRODUCTION

The importance of maize in prehistoric South America as a subsistence and ritual crop is a well-documented, albeit controversial, phenomenon (*e.g.* Johannessen and Hastorf 1994; Pearsall 1992, 2002; Staller and Thompson 2002). Evidence of the spread and use of maize is derived from isotope studies (Hastorf and DeNiro 1985), charred macroremains (*e.g.* Hastorf 1993; Pearsall 1992, 1994), phytoliths (*e.g.* Pearsall 1978, Pearsall and Piperno 1990; Pearsall *et al.* 2003), and recently, starch grains (*e.g.* Pearsall *et al.* 2004; Perry *et al.* 2006). Maize first makes an appearance in coastal Ecuador by 6000-4000 BC (Pearsall and Piperno 1990), spreads to coastal Peru by the beginning of the Initial Period (1800/1200-900 BC) (Pearsall 1992). The widespread occurrence of maize in archaeological sites is commonplace in Ecuador by at least 1200-500 BC, and coastal Peru by the Early Horizon (900-200 BC) (Pearsall 1992). By the Middle Horizon, maize is an important component in the assemblages of the highland states of Wari and Tiwanaku (Wright *et al.* 2003).

However, the spread of maize to the highland Andean regions of Peru and Bolivia after the introduction of maize during the Initial period is not well understood. In the central Andean highlands, the first evidence for maize is at 3600-4000 bp at Waynuna (Perry *et al.* 2006) and 3100 BC at Ayacucho in Peru (Pearsall 1992). Maize also appears in the pollen record at 500 BC in the Cuzco region (Kendall and Chepstow-Lusty 2006). It is important to track the spread of maize, along with other indicators of sociopolitical

complexity, in these regions because of the importance of maize in ritual and economic life.

BACKGROUND

The evidence for maize in the Lake Titicaca basin is sporadic. Archaeobotanical analysis at Tiwanaku and related sites suggests that maize forms an important component of the economic system, as it is the second most common identified taxon, ranking at 25% percentage presence (Wright *et al.* 2003). Based on a study of maize varieties, Tiwanaku maize was probably imported (Hastorf *et al.* 2006). Indeed, the altiplano environment characteristic of the Tiwanaku and the Lake Titicaca basin as a whole is above the elevational limit of successful maize cultivation. While some isolated microzones along lake edges permit cultivation of small-cobbed maize today (Pers. observation; Hastorf *et al.* 2006; Wright *et al.* 2003), it is not possible in the inland Tiwanaku Valley. While maize may have been cultivated around lake edges, it was probably quite limited and not viable on a major scale. Instead, it appears that domesticated quinoa, which is highly adapted to the altiplano region, was probably the focus of prehistoric agriculturalists (Browman 1986; Bruno and Whitehead 2003; Wright *et al.* 2003).

While maize appears to be an import at Tiwanaku (Hastorf *et al.* 2006), it is unclear how far back in time this pattern extends. The small amount of maize found at Taraco Peninsula sites during the Formative period precludes determination of origin. Recent phytolith data suggests the presence of maize in four ceramic residues from Yaya-Mama Tradition sites on the Copacabana peninsula, dating to 2750 BP (Chávez and

Thompson 2006)[9]. Maize produces abundant phytoliths, including several diagnostics for leaf and cob material, as well as diagnostic starch grains in kernels. The availability of diagnostics for each major plant part (leaf, cob, kernel)[10] makes it possible to test the hypothesis that maize was traded in, versus cultivated locally. If maize is grown in the region, both cob and leaf material should be represented in the microfossil assemblage; in other words, both product and byproduct should be present. If maize is not grown locally and is instead traded in, one would expect evidence for only the primary product—maize kernels and/or cobs. Maize may have been transported either on the cob (with leaf material removed), or in shelled form (with the cob removed, but probably still with cupule material inadvertently attached).

IDENTIFICATION OF MAIZE USING PHYTOLITH ANALYSIS

Phytolith production in maize has been intensively studied in South, Central, and North America (see Pearsall 2000:378-392 for a review; *e.g.* Piperno 1984; Hart *et al.* 2003; Mulholland 1993). Both diagnostic and assemblage based methods exist for identification of maize. Diagnostic methods rely on individual phytolith types to identify a specific taxon. Prospective types are compared to phytolith assemblages in other taxa in related plant families to test for redundancy[11]. If too much overlap is encountered with other plant taxa, the type is abandoned. If little redundancy is encountered, and the form

[9] The Chávez and Thompson (2006) study was not published until after the completion of the analysis presented here.

[10] Different diagnostic phytoliths are produced in the leaf and cob of maize. Diagnostic starch grains are produced in maize kernels.

[11] The reasoning in testing related taxa is that phytoliths are produced along taxonomic lines. Therefore, closely related taxa are expected to produce similar phytoliths. As such, they are the most likely to produce redundant types (*i.e.* in its area of origin, domesticated *Zea mays* diagnostics had to be tested against the local wild *Zea* representatives, as they are most closely related and likely produce similar phytoliths). This provides a rigorous evaluation of potential types, some of which have to be either abandoned, or examined closely for subtle morphological and size differences. For this reason, analysts favoring diagnostic approaches often insist on three-dimensional viewing of individual phytoliths (Pearsall 2000; Piperno 2005).

is unique to a taxon of interest, the type definition is usually refined after extensive testing against possible confuser species. In this way, diagnostic approaches can identify a particular taxon with a single microfossil type, so long as it has been thoroughly tested against the regional flora. Such approaches are usually regionally specific, and require a considerable amount of comparative work (Piperno 2005).

Assemblage based approaches rely on the phytolith assemblage of a particular taxon as a whole for identification. Ideally, phytolith assemblages from a taxon of interest are compared statistically to assemblages from possible confuser taxa, and refined as needed. Some analysts using an assemblage approach DO test their methods against local wild taxa before attempting archaeological identifications (*e.g.* Mulholland 1993); some analysts only compare archaeological assemblages to the taxon of interest (maize) and do NOT test local wild confusers (Chávez and Thompson 2006; Hart *et al.* 2003; Staller and Thompson 2002). This distinction has considerable implications for the accuracy of identification methods, and frames much of the present research.

Identification of maize using the diagnostic approach has seen intensive study. Maize produces diagnostic large cross-shaped bodies in the leaf, as has been described extensively by Pearsall and Piperno (Pearsall 1978, 1979, 1982; Piperno 1984; Pearsall and Piperno 1990). As cross-shaped phytoliths are produced predominantly in panicoid grasses, they were expected to stand out in the festucoid dominated grass assemblage of the highland Andes; however, this is complicated by whether or not leaf material is present in ancient highland contexts. It is suspected that maize was not grown at all or only rarely in the ancient Titicaca basin. As such, any maize that may have been imported. In this scenario, it is likely that leaf material would not be present, or would

appear in very limited amounts, hence archaeological remains may be limited to cob and kernel material. Furthermore, examination of comparative maize husk local to the Taraco peninsula showed few to no large cross shaped bodies in the husk, a case documented occasionally elsewhere (Mulholland 1993; Pearsall 1979)[12]. Perry *et al.* (2006) have also noted the absence of large and extra large crosses in highland comparative maize and archaeological samples, suggesting that small or medium crosses are more characteristic of these varieties. Therefore, while crosses of any size may indicate maize leaf material, small and medium crosses and bilobate forms are also found in wild panicoid grasses, complicating the evaluation of the presence or absence of maize byproduct material at TAP sites.

For these reasons, it may be most useful to use maize cob body diagnostics, described in Bozarth (1996), Mulholland (1993) and Pearsall *et al.* (2003) to identify maize in artifact residues and archaeological soil samples. The primary diagnostics found in the maize cob are the ruffle-top rondel and wavy-top rondel, as well as glume bodies with speculate projections. The use of diagnostics to identify maize (or any other plant) is based on viewing phytoliths three-dimensionally, that is, by rolling them by pressing on the slide cover while viewing through the microscope. However, the cob body method has not been systematically tested for use in festucoid-dominated grasslands. Since both simple and complex rondel forms are produced most abundantly in the festucoid grasses (Fredlund and Tieszen 1994; Mulholland 1989, 1993; Twiss *et al.* 1969), a thorough comparative study of wild grasses in the highland Andean region was conducted.

Interestingly, assemblage based methods for maize identification were first explored within the context of festucoid dominated grassland sites. Mulholland (1993),

[12] No local maize leaf was available for this study.

working in North Dakota, found that maize leaf cross body types were not produced abundantly in local maize races, a pattern that may also characterize Andean maize (Perry *et al.* 2006). She tested the cross body method (Pearsall 1978; Pearsall and Piperno 1990; Piperno 1984) on a late period archaeological site, where maize was known to be present ethnographically, and found little evidence using this method. Instead, Mulholland (1993) pioneered the use of an assemblage-based method that relied on maize inflorescence phytoliths, including the ruffle top rondel. Using constrained linear regression analysis, she used data from 19 wild grass species (mainly festucoid) and maize, and was able to trace the presence of maize archaeologically. However, Mulholland (1993) noted that rondel types are produced in many festucoid grasses, and can be confused with maize.

Other studies have identified maize in ceramic residues on the basis of rondel assemblages (Chávez and Thompson 2006; Hart, Thompson, and Brumbach 2003; Staller and Thompson 2002). Thompson bases his method on the assumption that within a pot, phytoliths from food residues will be concentrated. His multivariate method is based on analysis of rondel forms in different maize races. The rondel forms are viewed two-dimensionally, or in planar view, and counted. Hart *et al*. (2003) focus on archaeological sites in New York, which, like the present study, lie within a festucoid dominated ecozone. However, Thompson, while acknowledging that rondels are produced in 'wild grasses', does not report on any wild grass comparative data. Based on the TAP study, there is considerable overlap between rondel forms in festucoid wild grasses and maize, suggesting that in any given study region, it is necessary to conduct comparative research on these potential confusers.

Thompson's method relies on the assumption that within any pot, one will only find food residues, or at least these plants will form the major part of the assemblage that would be identified based on multivariate statistical methods. His identifications of maize appear to be based on observations of rondel forms in pot residues, which, while they are produced in many wild grasses, are assumed to "logically" indicate maize because of their context, *i.e*. carbonized pot residues (Staller and Thompson 2002:42). Hence, there is no need to examine wild grass comparative samples, as these would not be part of a food assemblage. However, people are known ethnographically to consume wild grasses in North America (Doebley 1984), and archaeobotanical evidence suggests that ancient South Americans in the Lake Junin and Lake Titicaca regions probably did the same (Lee 1997; Pearsall 1989). Wild grass seeds are a significant component of macrobotanical samples in the Titicaca region (Browman 1986; Lee 1997; Whitehead 1999b; Wright *et al.* 2003), although they could derive from fuel use, rather than consumption. Secondly, wild grass phytoliths are a significant component of temperate soils. If any soil (visible or not) is incorporated in the ceramic residues at the time of their deposition or afterwards, so too are the wild grass phytoliths; it is practically unavoidable. This is supported by data presented in Staller and Thompson (2002:42) Table 6, where counts of different short cell types in the ceramic residues are reported. Interestingly, a few saddle shaped short cells occur in the residues, which are typically interpreted as representative of chloridoid grasses (Twiss *et al.* 1969), and are not found in maize inflorescence material, suggesting that wild grass phytoliths form part of pot residue assemblages (whether related to diet or contamination from soil).

The aim of the present study is to test current diagnostic methods for identification of maize on the Taraco Peninsula, and evaluate the potential of an assemblage based method for this area. Both goals are accomplished through extensive comparative work on local wild grass genera in order to build a precise identification methodology specific to the highland Andes. Currently no maize identification methods have been developed specific to Andean highlands, rather, methods from other regions (lowland tropics and North America) have been applied without thorough testing against local flora.

COMPARATIVE PLANT STUDIES

A list of comparative grasses was compiled for highland Bolivia based on Renvoize (1998), and for highland Ecuador based on Jorgensen and León-Yánez (1999). All native grass genera found above 3000 masl in both countries were sampled, and multiple species were sampled for particularly large genera. While this study focuses on festucoid grasses, the few panicoid, chloridoid, and arundinoid grasses found in highland regions were also included. In total, inflorescence and leaf material from 36 genera and 52 species were selected for analysis, totaling 106 samples (see Appendix 3B). The aims of this study include characterization of festucoid grasses typical in these regions, establishment of diagnostic short cells in Andean grass genera, investigation of potential overlap with maize inflorescence diagnostics, and finally, collection of quantitative data to aid in construction of a multivariate statistical method for identification of maize specific to the Andean highlands.

Most samples were processed using the dry ashing technique (Pearsall 2000). As some processing problems were encountered in Spring 2005, we switched from chemical processing to the dry ashing method of comparative processing for the majority of the

samples (approx. 80)[13]. Short cells were counted to 50 or until the whole slide was scanned. When possible, many samples were processed and analyzed twice to ensure adequate counts were reached. All new forms were drawn and tallied as part of the count.

After scanning was completed, all new phytolith forms were examined and transcribed onto cards with provenience (taxon, part) information. These cards were then ordered and grouped into types intuitively. The typology was established based on several attributes, with the idea being that all types were sufficiently different to be identifiable to the analyst in archaeological soil samples. They were first divided by base/general shape, then view from sides, view from top, and finally, decoration. These types are meant to be employed only by rolling phytoliths and establishing their three dimensional shape. Mulholland (1993), who studied festucoid grasses in North America, and Piperno and Pearsall (1998a) were consulted as general guides. Possible maize confuser types were separated out and compared more closely to modern Andean maize samples.

The typology was created for the high elevation Andes only, and was not compared to lowland grass data available in the MU laboratory, as it is meant to be applicable only to highland sites. As such, it was possible to establish a number of diagnostics applicable to TAP sites and other Andean sites above 3000m in elevation. This study is helpful in delimiting the nature of phytolith production in festucoid grasslands of South America, and may have wider applicability to festucoid grasslands in other regions (*i.e.* North America). The overall frequency distribution of these types in all comparative grasses is illustrated in Figure 6.1.

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[13] Samples processed by ashing and chemical procedures are comparable as in both instances the silica is isolated, and there is little reason to think that one or the other method yields different results so far as silica is concerned. Problems with the chemical extraction procedure caused several grass specimens to be completely destroyed, in which case they were re-processed using dry ashing.

The typology (Figure 6.2; Appendix 3C) is arranged hierarchically, following Pearsall and Dinan (1992). For instance Type 3Ag has an elongated rondel base (3), comes to a keel or ridge at the top (A), and is roughly semi-circular or kidney-bean shaped (g). This type has been further designated "*Festuca* Inflorescence Type", as it is produced only in *Festuca* and is of special interest. The abbreviations (*e.g.*, 3Ag) will be adopted in subsequent statistical analysis for ease of display.

In addition to morphological and typological attributes, quantitative data were also collected for later statistical tests. All short cells were counted to 50 (with a few exceptions), as most comparative grasses hit redundancy at this point. While this is at the low end of the range for redundancy, the large number of samples analyzed precluded any larger counts. In addition, given that comparative grass samples represent a 'pure' phytolith assemblage of that particular taxon, it is not necessary to reach counts of 200, which is typical in the analysis of soil samples, which are 'mixed' assemblages.

Seven Andean maize varieties, including Taraco Peninsula varieties, were studied in order to establish phytolith production patterns for this region. Inflorescence material was sampled for all seven varieties, and leaf material from two. Shape data was recorded, and short cells counted to 50, in order to be compared to the wild grass data reported on above. Specific attention was devoted to testing several inflorescence diagnostics used in the lowland tropics against festucoid inflorescence cells.

Many wild species produced wavy top rondel confusers. At this time, separation of these confuser forms in wild grasses from those in maize is difficult to impossible, and, at the very least, impractical. First, wavy top rondels are rare in maize in general, and I

Figure 6.1: Overall Frequency of Grass Types

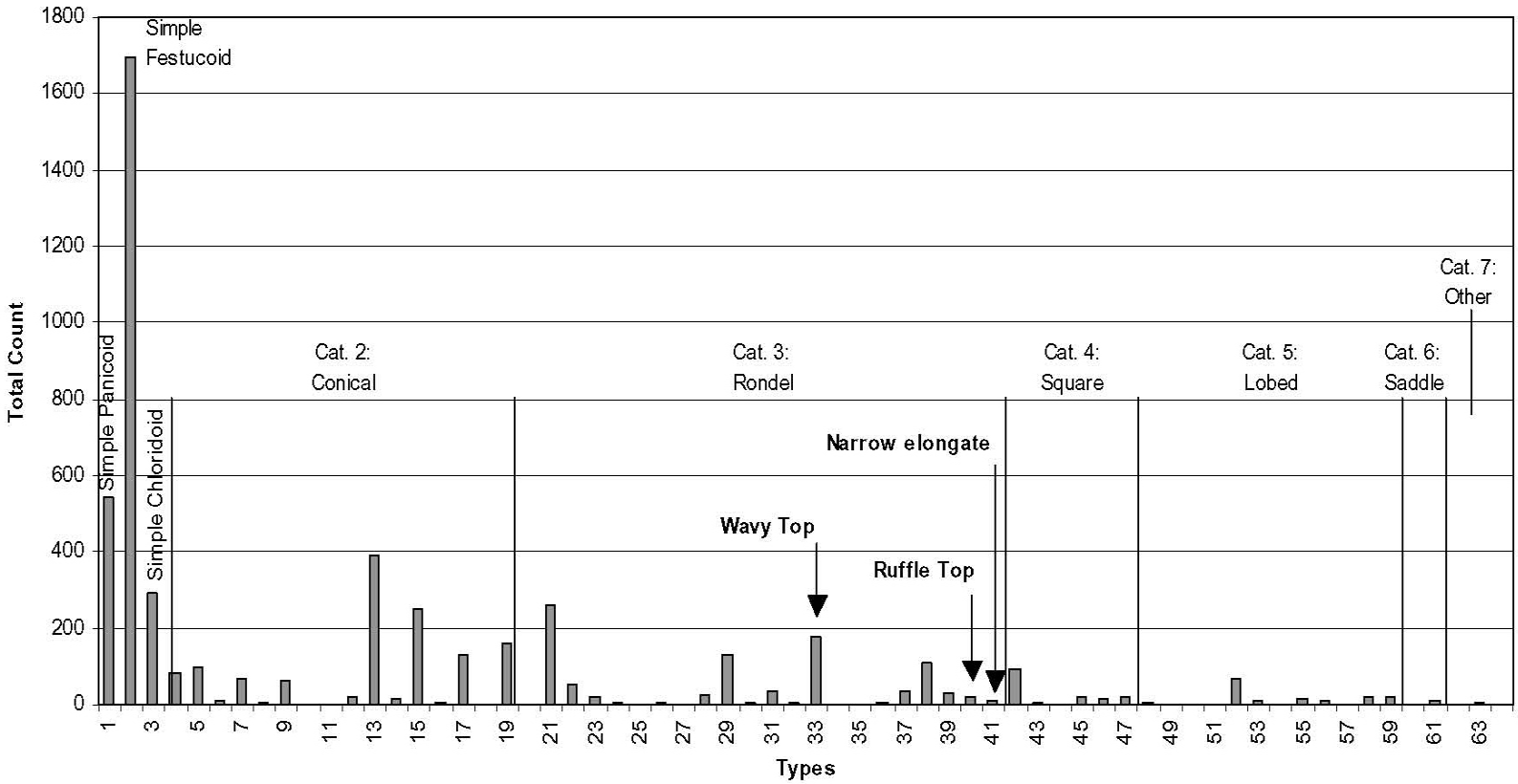


Figure 6.2: Simplified Andean Highlands Complex Short Cell Classification

Category 1: Simple (not classified further): top and base are mirror-images

Lobed base
Rondel/rectangular/sinuous base
Saddle base

Category 2: Conical (circular base): top is smaller then base, general 3-D shape is conical

A: Conical, Flat Plateau Top: Base is generally circular to slightly irregular; sides are generally slanted to flaring at base, may be shouldered

a. Very small cone, top is flat to bifurcate, sides almost straight→*Sporobolus* DIAGNOSTIC
b. Tall, large, heavily silicified cone with nearly straight sides and plateau top→*Elymus* DIAGNOSTIC

B. Conical, Rounded, Decorated Top: Base is circular, sides often flare sharply at base, top is covered in small rounded projections or bumps

a. Tall, cylindrical body with bumpy top

C: Conical, irregular top: top is ephemeral to almost decorated or spiked, but very thin and hard to distinguish, bodies generally thin and tall

a. Extremely thin, small top ("pencil-like") with irregular, ephemeral top that is almost spiked, sides flare sharply outwards half-way down, base is circular to rondel→ *Piptochaetium* DIAGNOSTIC
b. Three low spikes on top, sides slant slightly
c. Bifurcate top, with circular base

D: Conical, pointed top: top comes to point in side view and from top, or may be more open and flat at top

Flattened, elongated rondel base with pointed top→ *Calamagrostis* DIAGNOSTIC

E: Conical, thin ridge top, concave, flared sides

a. Long thin upper half, flares dramatically at base, ruffled circular base
b. With decorated base
c. Two-spiked top→ *Aciachne* DIAGNOSTIC

F: Domed, thin top

Category 3: Rondel base: elongated oval base

A: Classic to irregular rondel base, top comes to keel ('ridge'), usually elongate

a. Slanted sides, triangular
b. Sides flare only at base
c. Straight sides, three thin spikes on top→ *Elymus* DIAGNOSTIC
d. Slanted sides, triangular, three thin spikes at top→ *Calamagrostis* DIAGNOSTIC
e. Sides concave, flare sharply at base and top, three spiked→ *Brachypodium* DIAGNOSTIC
f. Sides flare at base, concave, two spiked top, more square from side view→*Agrostis* DIAGNOSTIC
g. Distinct kidney-bean shaped base, ridge top is semi-circular and meets edge of base from top view, top is flat or two spiked → *Festuca* Inflorescence Type DIAGNOSTIC
h. Ephemeral to spiked top, very thin, curved, convex or straight sides, rondel base [could be confused with wavy top, but top does not wave, it is much more ephemeral and irregular]
i. Sinuous rondel to rectangular base, top is ephemeral to spiked, sides concave→ *Dissanthelium* DIAGNOSTIC
j. Elongate, thin, sinuous base, concave sides, flat ridge top→ *Stipa* DIAGNOSTIC
k. Elongate, thin, sinuous base, straight sides, pointed edges on top
l. Wavy top rondel: sides are straight but may curve outwards at base, top does not form spikes but 'waves', i.e. is not straight, base is classic rondel to irregular, very similar to 3Ah

Category 3: Rondel base, continued

B: Flat, 'plateau' top, straight sides

a. Elongate, sides flare out slightly, top has central point from side view
b. Base is irregular and ephemeral, top not parallel to bottom, but slanted, flat circle:
c. Ruffle Top Rondel Confuser: Base is circular to rondel, top is nearly the same size and 'roughly' silicified to ephemeral, can be confused with ruffle top, but much more irregular (i.e. its ephemeral, but not indented/ruffled top)
d. Three or more long, rounded spikes, base irregular rondel
e. Ruffle top rondel, very similar to 3Bc, but top is distinctly ruffled/indented, not just ephemeral but forms a distinct design, sides are concave to straight →**MAIZE DIAGNOSTIC**
f. Narrow elongate rondel: sides distinctly concave, top is slightly smaller than bottom, both top and bottom are oval or elongated rondel, may be somewhat irregular, top is flat not waved or peaked→**MAIZE DIAGNOSTIC**

Category 4: Square/rectangular base

A: Rectangular base, slanted sides, ridge top→ *Poa* DIAGNOSTIC

B: Plateau top (looks like smaller rectangle/oblong inside bigger rectangle from top), sides flared to straight

a. Sides concave, flare at top, elongate
b. Base square, top ephemeral to spiked, sides straight to slanted

Category 5: Lobed base

A: Small, squat, unpronounced bilobate base, top is ridged to plateau

B: Cross base: irregularly ridge or spiked top, elongate→ *Andropogon* DIAGNOSTIC

C: Two-spiked top, elongate, bilobate to nearly sinuous base, concave to slanted sides

a. Two-spiked top, but very tall and straight sided, with squat bilobate base→ *Aegopogon* DIAGNOSTIC

D: Four-spiked top, squat bilobate base

a. Spikes are long and rounded, not on corners→ *Andropogon* DIAGNOSTIC

E: Ephemeral top, Bilobate base with very thin shank, small, irregular plateau top, sides flare at base→ *Cortaderia* DIAGNOSTIC

F: Three or four lobed base, distinct square plateau top, but top is ephemeral from side view→ *Aegopogon* DIAGNOSTIC

Category 6: Saddle base

A: Extremely squat saddle base (twice as wide as long), ridge top, curved to wavy in side view→ *Erioneuron* DIAGNOSTIC

B: Small saddle based, ridge top, sides slant outwards at base→ *Eragrostis* DIAGNOSTIC

Category 7: Other

A: "U-shaped" base, sides straight to slightly curved, flat plateau top→ *Koeleria* DIAGNOSTIC

B: Base is distinct; three lobed to two indentations per side from top view, top is plateau → *Festuca* DIAGNOSTIC

C: Short, square cross→ *Trisetum* DIAGNOSTIC

For full data and taxa information, see Appendix 3.

could not locate them in the Andean maize varieties tested. Second, they are also rare in many of the overlapping wild grasses. There is a gradient between many rondel forms produced in festucoid grasses and the wavy top rondel. Rondel forms are quite variable in wild festucoids; the separation between these and wavy top rondels characteristic of maize is arbitrary and perhaps not possible.

Ruffle top rondels are a much more useful type. While there is considerable overlap in general form with wild festucoids, the two types can be separated. Festucoids do produce a circular, rondel base phytolith with a flat, ephemeral top. Only maize produces an ephemeral topped rondel that is distinctly indented or ruffled—this form is much more regular in maize, and very variable and irregular in wild grasses. The type can probably still be used as a maize diagnostic, however, a maize identification should be confirmed by other indicators.

In short, it may be possible to recognize the wavy top and ruffle top rondel maize diagnostics defined for the lowland Neotropics in Andean archaeological samples; however, the type definitions must be followed precisely. Even so, the method will under-identify maize or not recognize it at all [a problem also noted by Mulholland (1993)], and will inevitably involve a certain margin of error due to overlap with wild festucoid grasses. If, as is expected, maize is rare in the TAP sites, these problems become considerable. The maize inflorescence diagnostics are not appropriate for maize identification at TAP sites. Instead, the development of maize cob diagnostics specific to the highland Andes, and/or creation of a multivariate method for tracking maize may be more useful for this region.

AN ASSEMBLAGE-BASED APPROACH

Given the difficulties with separating complex rondels in festucoid grasses from those diagnostic of maize inflorescences, an assemblage-based approach may be preferable for identification of maize in festucoid-dominated grasslands. Using count data gathered for each of the wild grasses studied (n=97), as well as seven different varieties of maize (n=9), several different statistical techniques were employed, including basic ratios and correlations, Principal Components Analysis (PCA), and Discriminant Analysis (DA). All grass taxa were abbreviated and coded for ease of display.

The first step was to examine the data for any patterning that might be present at the outset. Preliminary inspection of the data (Appendix 3) revealed the presence of several categories with few data values (*i.e.* certain types were only present in small amounts in one species). Because PCA picks up on even the slightest variation, types with few or very small data values may obscure the amount of correlation between major categories (Hillman 1984). Therefore, several of the types were amalgamated into more inclusive categories (*i.e.* types 3Aa, 3Ab, 3Ac, and so on were grouped into 3A) (refer to Figure 6.2), increasing the values for each type, reducing measurement error, and allowing for a more accurate statistical reflection of the data. This involved simple summation of the types in each respective major category, therefore no data was lost or ignored in the amalgamation. Indeed, application of PCA and other multivariate methods prior to summarizing the data produced very complex and unproductive results.

After this grouping, clear patterning was evident in the data matrix that had been obscured given the complexity of the raw data table. For the present purpose (separation of maize from wild grass assemblages), the following patterns emerged:

1. Maize has particularly large amounts of Category 3B (plateau top rondel), while wild grasses, including festucoid, chloridoid, and arundinoid taxa, only produce this type sporadically and rarely. Maize inflorescences, on the other hand, always contain large quantities of plateau topped rondels. This category includes the ruffle top rondel, as well as several generalized forms. However, category 3B does appear in some festucoid taxa in amounts similar to maize (*Trisetum spicatum* L[14], *Elymus erianthus* IN, *Catabrosa werdermanii* LF, in small amounts in *Bromus segetum* IN, *Festuca subulifolia* LF, *Piptochaetium stipoides* IN, and *Poa nevadensis* LF), so additional criteria are needed to confidently separate maize from wild taxa.
2. Category 2 (conical shaped short cells) is limited primarily to wild festucoid grasses. They appear in only one maize sample (n=2), but form the majority of wild festucoid assemblages. They do appear sporadically in chloridoid, arundinoid, and panicoid grasses.
3. Generally, maize has lots of simple[15] panicoid short cells and NO festucoid simple short cells; festucoid grasses show opposite pattern—they produce lots of simple festucoid forms and very few panicoid forms.

[14] L refers to leaf; IN refers to inflorescence material.
[15] 'Simple' short cells are two-dimensional, i.e. both the top and bottom faces are mirror images of each other. There are three general types: panicoid (lobed), festucoid (square or circle), and chloridoid (saddle). They are separated from 'complex' short cells, where the top is not a mirror image, but has some decoration like spikes, waves, or points. Complex short cells are the focus here.

Table 6.1: Average values for important types in wild grasses and maize

Short cell type	Wild Festucoid	Wild Chloridoid	Wild Panicoid	Wild Arundinoid	Maize
Simple Panicoid	VR (0.9)	M (4.9)	**VA** (27.2)	**VA** (23.3)	M (7.4)
Simple Festucoid	**A** (18.2)	**A** (17.1)	**A** (18.4)	M (4.5)	VR (0.4)
Simple Chloridoid	VR (0.1)	**A** (17.3)	R (1.1)	None (0)	None (0)
Cat. 2: Conical	**A** (17.3)	M (6.3)	VR (0.1)	M (7.5)	VR (0.2)
Cat. 3A: Ridge top rondel	M (7.5)	VR (0.4)	None (0)	M (10.5)	**A** (17.9)
Cat 3B: Plateau top rondel	R (1.5)	None (0)	VR (0.6)	VR (0.3)	**VA** (22.2)

VA=Very abundant (>20.1), A=Abundant (10.1-20.0), M=Moderate (4.1-10.0), R=Rare (1.0-4.0), VR=Very Rare (<1.0)
Numbers in parentheses are average count values for all grasses of the category.
Highest values for each grass subgroup are denoted in bold.

Use of Simple Ratios

Given the patterns presented in Table 6.1, several ratios were devised in order to separate maize from wild grasses. Although forms produced in maize are also produced in wild grasses, the amounts of these types in each taxon differ significantly. Therefore the objective of establishing ratios was to track the true contribution of different types to each assemblage (Miller 1988). Using two simple ratios, maize can be separated from all wild grasses. These ratios are:

1. **3B / (3B+Conical+Simple Festucoid):** This ratio compares the amount of plateau topped rondels (Category 3B) to the amount of conical and simple festucoid forms, which are found predominantly in wild festucoid grasses. It essentially separates out maize from the wild festucoid grasses, as well as some panicoid, arundinoid, and chloridoid grasses. Panicoid, arundinoid, and chloridoid grasses for the most part do not produce rondel forms.

2. **3A / (3A+Conical+Simple Festucoid)**: This ratio compares the amount of ridge top rondels (Category 3A) to the amount of conical and simple festucoid bodies. This ratio serves to separate out maize from remaining festucoid grasses, as well as arundinoid, panicoid, and chloridoid grasses. Panicoid, arundinoid, and chloridoid grasses for the most part do not produce rondel forms.
3. **3B / (3A+3B)**: This ratio compares the amount of plateau top rondels to all rondels. Since festucoid grasses produce moderate amounts of ridge top rondels (3A), and small amounts of plateau topped rondels (3B), and maize produces both forms, but in differing amounts, this ratio is helpful as another way of increasing separation between the two groups.

Using these three ratios, maize clearly separates from <u>all</u> wild grasses. Values for Ratio 1 for maize varieties hover around 0.9 to 1.0. For festucoid grasses, the values are extremely small for the most part, ranging from 0 to 0.62. Taxa with values over 0 are rare. Panicoid, chloridoid, and arundinoid grasses generally have values of 0 as well, with a couple exceptions. Therefore, while Ratio 1 separates maize from the vast majority of wild grasses, another ratio should be used for absolute assurance.

Ratio 2 takes the amount of ridge top rondels into account. Again, maize Ratio 2 values are 0.9 to 1.0. Values in wild grasses are generally small. Festucoid grasses Ratio 2 values are more variable then those for Ratio 1, ranging from 0 to 0.89. While the majority of values hover around 0, there are a few instances of large values that overlap with maize. The same pattern is evident in panicoid, chloridoid, and arundinoid grasses, with values generally clustering around 0, but with a few odd examples of large values. However, few taxa have large values for Ratio 1 <u>and</u> Ratio 2.

Ratio 3 was devised to confirm and clarify the differences between maize and wild grasses. Both maize and wild grasses contain ridge top rondels (Type 3A), but maize also contains relatively large amounts of plateau top rondels (Type 3B). This ratio serves to clarify this separation. Values of Ratio 3 for maize ranged from 0.26-0.86, but most clustered around 0.7-0.8. In wild grasses, Ratio 3 values had similar ranges, but most were concentrated in the under 0.5 level. While this ratio is not as useful as Ratios 1 and 2, it is an alternate way of looking at the variables that separate maize from wild grasses. Importantly, when all three ratios were applied to the comparative plant samples, maize clearly separated out from wild grasses.

However, problems were encountered when the method was applied to test soil samples. Two test samples were selected based on a high probability that they contained maize. The first was a comparative soil sample from a field where maize was grown very close to the site of Sonaje (MU 2649). The second was an archaeological artifact residue sample from Sediment 2 of a mano (MU 2291). Maize starch was located in Sediment 3 of the same mano (see below). Therefore, both samples should contain phytoliths indicative of maize, and as such, are the most appropriate tests at present for the ratio method.

Unfortunately, values of Ratios 1 and 2 for the test cases were 0.20-0.38. While this value is greater than those found in most festucoid grasses, there could be some overlap if wild grasses contributed to the assemblage. Values for Ratio 3 hovered around 0.7, similar to maize, but also within the range of wild grasses. Wild grasses are undoubtedly part of the assemblage, given the high amounts of simple festucoid and conical bodies. The result of the test is therefore mixed—background noise is obscuring a

maize signature. In addition, there is the issue of a mixed assemblage, namely that a number of grasses, perhaps including maize, contribute to the assemblages of the test cases and any archaeological sample. The possibility exists that moderate values for Ratio 1 and 2 are the result of the contribution of several different festucoid grasses and no maize. Therefore, while maize comparative samples can be easily separated from wild grass comparative taxa, the related problems of admixture and background noise prohibit the full application of this technique for archaeological identification.

What is needed is a 'correction factor' that accounts for the background noise that is composed of wild grasses. An estimation of the contribution of maize phytoliths to the total assemblage would be helpful *if* there was some basis to expect that a soil sample contained, for example, 10% maize and 90% wild grasses. However, at this point, there is absolutely no precedent for either of these measures. In order to accurately construct such a method, a secure basis for estimation or correction factors must first be established. While it is appealing to use the test samples described above, that have a high probability of containing maize, there are taphonomic problems that prohibit this approach. The first is that in the case of the maize field, there is too little known about the nature of and time frames for phytolith deposition to know if any maize phytoliths have even been incorporated (through decay) into the soil matrix. If the field was cultivated with maize for one or two years, the amount of phytolith deposition may not yet be sufficient. The other issue is that one would not expect inflorescence material to be deposited in a field—deposition of leaf material makes a lot more sense, intuitively speaking.

An alternate approach would consider the assemblage of a soil sample known to NOT contain maize. Several comparative soil samples were collected from the Taraco

Peninsula. Scatter samples were taken from approximately 10x10m plots, and vegetation cover was estimated. The areas in the region that are least likely to have been used for agricultural production are those on the hilltops (M.C. Bruno pers. comm. 2006). This is also the area with the least amount of introduced, European grass species. Introduced grasses are problematic in this case because 1) they may produce short cell forms that overlap with maize, and 2) their colonization of different ecological zones may change the structure of the grassland, helping some species increase, and some decrease or disappear.

Unfortunately, only a small number (n=2) of comparative soil samples meeting the right criteria (uncultivated, low percentage of introduced grasses) were available. However, the samples can be used as 'controls' to predict the appropriate ratios in a completely wild, maize-free grassland. Importantly, they were used to predict values of ratios for the null hypothesis—no maize. One comparative soil sample collected from a hilltop near the sites of interest was analyzed for comparative purposes. There had been no obvious cultivation recently, and even if it had been cultivated at some point, it is highly unlikely that maize was grown (M.C.Bruno pers. comm. 2006). There was also a relatively low percentage of the primary introduced grass (approximately 20%). Surprisingly, the values for the ratios as well as useful short cell types were similar to those defined for the samples known to contain maize tested above. In fact, there was no significant difference in ratio values between samples that contained maize and those that did not. Ratios 1 and 2 could be explained as products of mixtures of different wild grasses and perhaps maize. However, the values for Ratio 3 for both the archaeological mano and control sample are much higher than maize or wild grass. The values for wild

grasses and maize reported in the table are only average values; some wild grasses and some varieties of maize have particularly high values for Ratio 3. The overall similarity between known maize and control sample ratio values suggests two possibilities: 1) maize phytoliths were not deposited in the samples thought to contain maize, or 2) use of ratios as a means to discriminate between assemblages with and without maize is not a reliable indicator of maize.

Table 6.2: Ratio values for comparative maize, grasses, and soil samples

Sample Description	Ratio 1	Ratio 2	Ratio 3
Wild grass average[16]	0.032	0.141	0.054
Maize average	0.933	0.935	0.567
Archaeological mano with known maize (2291 test)	0.275	0.121	0.733
Modern maize field (2649 test)	0.258	0.207	0.571
Control sample with no maize (2648 null test)	0.310	0.091	0.818

Multivariate Techniques

Given complications with using simple ratios, a number of exploratory statistical techniques were performed on the data in order to characterize the overall structure and develop an alternate method of discriminating between maize and wild grasses. These included the multivariate techniques of cluster analysis (CA), principal components analysis (PCA), and discriminant analysis (DA). Baxter (2003), Green and Salkind (2005), and Hair *et al.* (1995) were used as general guides. Refer to Appendix 3 for full results.

Early applications of CA and PCA used all of the data, in its unsummarized and uncondensed form, in other words, data values for every type category and every grass taxon were inputted, accounting for well over 6500 observations or cells (Appendix 3E).

[16] Please note that only average values are provided for the wild grass and maize comparative samples, for ease of display. Inspection of the full data (Appendix 3) shows that values for a few wild grasses are very close to that of maize.

This produced quite complex and confusing results, with over 10 principal components required to fully separate the taxa. These results were very difficult to interpret. As alluded to above, a major problem with throwing all the data into PCA occurs when several cells contain very low values (0 or 1), as PCA is very sensitive to small sources of variation that are often irrelevant.

Both cluster and principal components analysis separated out maize assemblages from wild grass assemblages, generally speaking. However, cluster analysis placed some maize varieties in with wild grass subfamilies. The separation was not completely clear using PCA either. Cluster analysis is useful for finding groups in ungrouped data, however in this case, the groups were already established, and so cluster analysis was not explored further. PCA is considered more useful as an exploratory, rather than confirmatory or predictive, approach (Hair *et al.* 1995). While it is a useful technique for characterizing the variation present in large data sets, acting as a data reduction technique, it is far less useful to group unknown or archaeological samples into the correct category (maize or wild). Indeed, for the most part maize separated out from wild grasses using PCA; however, the soil test samples described above did not clearly fall into one category or another.

Discriminant Analysis, on the other hand, can be used to accurately classify unknown or ungrouped samples into the correct category (Baxter 2003; Hair *et al.* 1995). Preliminary attempts were made to construct a discriminant function, however due to problems with uneven sample size (maize n=9, wild n=97), as well as the extreme difficulty of constructing discriminant functions, no further attempts were made.

Additional analysis of more maize varieties may help in the construction of a discriminant function, however it is beyond the means of the present study.

Overall, similar results were achieved with all forms of multivariate analysis. The same problems encountered with use of simple ratios were also problematic with multivariate methods. Namely, most methods can easily separate maize assemblages from wild grass assemblages, using either ratios or multivariate methods, results are similar. The known maize test samples, as well as the control sample, both fell somewhere in between wild grasses and maize, although far closer to the ranges of the wild species. The similarity of values for both known maize and no maize samples presented above (Table 6.2) represent one of the biggest challenges. At this time, use of an assemblage based method (based on ratios or multivariate analyses) to find maize in archaeological soil samples is not possible.

A DIAGNOSTIC APPROACH

> One should not increase, beyond what is necessary, the number of entities required to explain anything.
>
> -Occam's Razor

Difficulties encountered when using a multivariate, assemblage-based approach were in large part, surprising. Intuitively, maize, a panicoid grass, should stand out in meaningful ways in a festucoid grassland. However, a maize signature could not be traced in one artifact and one comparative soil sample known to contain maize. What was most telling was that the non-maize comparative soil sample yielded very similar values to the known maize samples. This suggests that assemblage based approaches are may not be an appropriate means of tracing maize in this region, particularly when maize occurs in small amounts. Additional Andean maize phytolith assemblages, as well as the problem

of mixed grass assemblages found in both soil and artifact residue samples, need to be addressed before any reliable assemblage based method can be fully developed.

While using already established diagnostic phytoliths to identify maize in the Andean highlands is appealing, comparative work on wild grasses indicates 1) that wavy top rondels are found not just in maize, but also in wild grasses of the highlands, and 2) the ruffle top rondel can still be used as a diagnostic for this region, however, one must adhere strictly to the type definition. Given that ruffle top rondels are difficult to separate from some wild grasses, and as they are produced in low to moderate amounts in comparative maize, use of solely this phytolith type will significantly under-identify maize.

One solution to this problem is to search for new diagnostics in Andean maize. Any diagnostics for domesticates from the grass family must take into account potential overlap with wild grasses. Because short cell forms of all wild grass genera of highland Bolivia and Ecuador were characterized for this study, any possible diagnostics for maize can be fully evaluated for use in these regions.

Close re-examination of the data suggests that one type stands out as a diagnostic for maize in the Andean highlands, in other words, it is produced only in maize. Originally classified as 3Bf (generalized plateau top rondel), and including a wide variety of rondel forms, the type has been subsequently redefined. The diagnostic rondel form in maize can be described as an elongate, thin rondel with concave sides that is heavily silicified, particularly the top and bottom faces (Figures 6.3 and 6.4), henceforth called 'narrow elongate rondel'. It occurs in moderate to abundant amounts in comparative

maize, often dominating assemblages. Importantly, this type was also noted as a potential diagnostic in Bozarth (1996:401), although no pictures are provided.

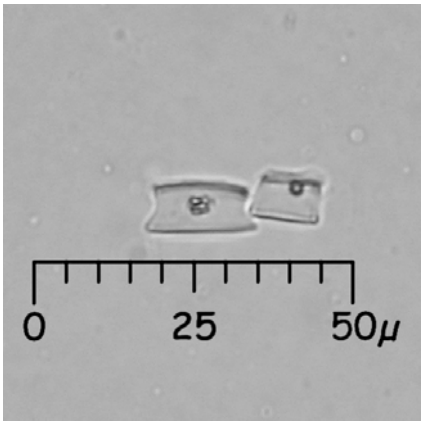


Figure 6.3: Narrow elongate rondel
Side view, Comparative *Z. mays* (N1461)

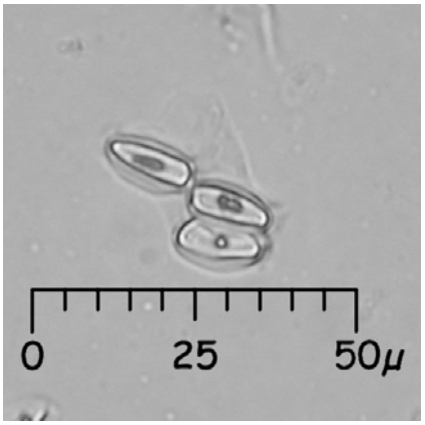


Figure 6.4: Narrow elongate rondel
Top view, Comparative *Z. mays* (N1459)

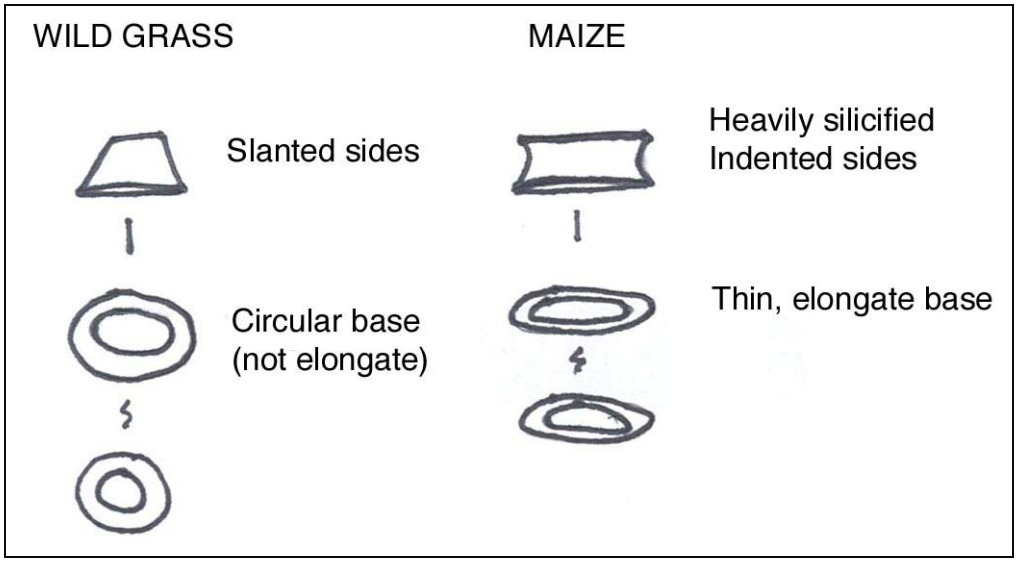


Figure 6.5: Stylized Drawing of Differences between Wild Grass Plateau Top Rondels and Maize Diagnostic (Narrow elongate rondel) (Not to scale)

Possible confuser forms were encountered in wild grasses, making it necessary to narrow the type definition. Other grasses also produce plateau top rondels, but they are always very irregular, the base is more circular (not elongated), and the sides are always slanted (not concave) with a significantly narrower diameter at the top (Figure 6.5). The elongated plateau top rondel in maize is instead quite regular (no ‘messy’ or lightly

silificed edges), the base and top are clearly oval and heavily silicified, forming thick lines from the side view. The sides are also almost always concave (Figure 6.5).

One other possible confuser with the elongated rondel is two dimensional simple festucoid bodes. However, narrow elongate rondels are much 'taller' than simple festucoids (in side view, approximately half as tall as wide), and the basal and top faces are not the same size. It is simple to separate narrow elongate rondels from simple festucoid bodies, in part because the narrow elongate rondel is often lying on its side; from this vantage it is clearly different from simple festucoid short cells. While the type may be confused with simple festucoid bodies viewed only in the planar view (cf. Hart *et al.* 2003), viewing each body three dimensionally (by rolling) allows clear separation of simple festucoids and the narrow elongate rondel.

The type should not be used outside of the Andean region without significant testing against local wild grasses. In the Andes, the type definition must be followed precisely. However, it does open up the possibility of identifying maize more often, solving, in part, the problem of under-identification of maize encountered if one relies solely on ruffle top rondels.

ARCHAEOLOGICAL RESULTS

Both diagnostic and assemblage based methods were presented above. The diagnostic approach designed for application in the highland Andes is based on the presence of two phytolith forms: the ruffle top rondel and/or the narrow elongate rondel. An attempt was also made to develop an assemblage-based method. However, due to the problem of background noise in archaeological samples, maize would have to compromise a significant portion of the assemblage in order to be recognized by

statistical measures. As stated previously, this is unlikely at TAP sites, where macrobotanical (M.C. Bruno pers. comm. 2006; Whitehead 1999b) and starch grain analysis (present study) suggest maize use was rare.

Artifact Residues

Artifact residues discussed in Chapters 4 and 5 were also examined for maize. Samples were re-scanned following the establishment of the narrow elongate rondel diagnostic. Results of starch grain analysis uncovered evidence for maize on four artifacts. The positive, known presence of maize provides a good test case for evaluation of the phytolith methods described in this chapter. In addition, examination of additional artifacts using phytolith analysis indicated additional maize signatures. Full data for the artifact residues can be found in Appendix 2A.

Identification of maize starch

Maize starch was positively identified on TAP artifacts based on published identification criteria (Pearsall *et al.* 2004; Piperno and Holst 1998). Maize starch grains are simple, with an open hilum positioned in the center of the grain. The shape of the grain is generally spherical to oval-spherical to polyhedral. Maize starch grains have a distinct double outline, and the extinction cross is crisp and narrow, meeting at a right angle. The size ranges from about 4-24 µm (Pearsall *et al.* 2004:430-431). Maize starch grains were positively identified on manos from Chiripa Quispe Loci 3114 and 3132 (Figure 6.6), a Tiwanaku 1 ceramic vessel from Kumi Kipa (Locus 6782) (Figure 6.7), and human teeth from a burial at Kala Uyni (Locus 5268).

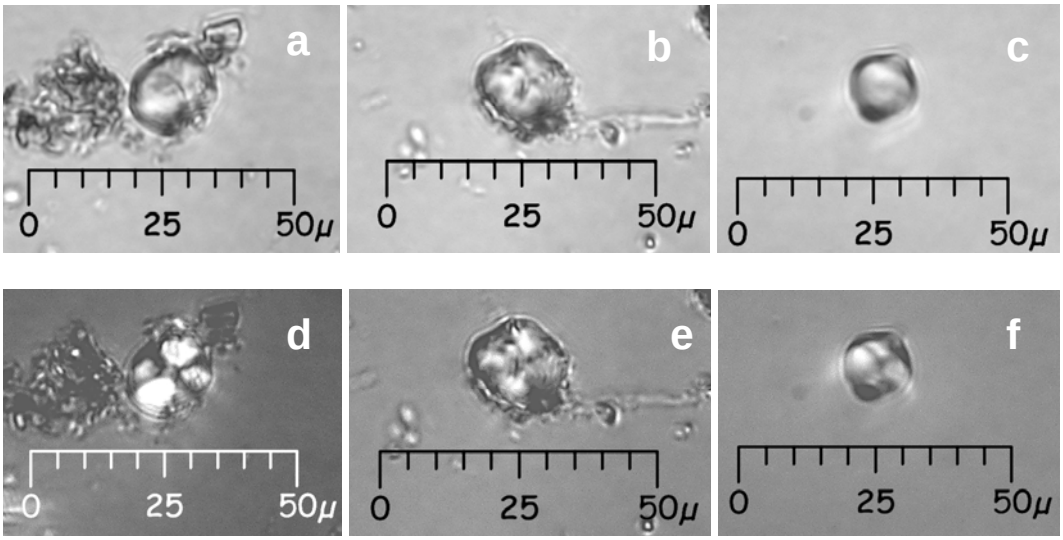


Figure 6.6: Maize starch grains on manos from Chiripa Quispe
Locus 3132, SS329: a) Granule 1 TL (N1255); d) Granule 1 PL (N1256);
b) Granule 2 TL (N1257); e) Granule 2 PL (N1258)
Locus 3114, SS311: c) Granule 1 TL (N1252); f) Granule 1 PL (N1251)

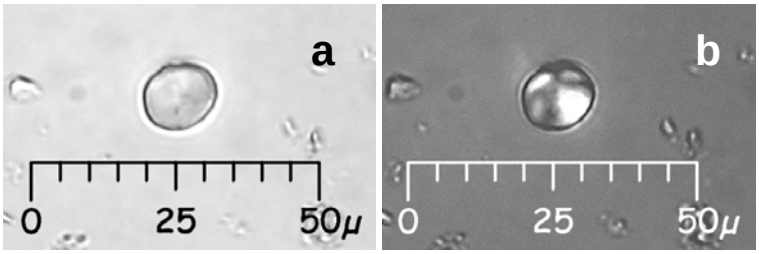


Figure 6.7: Maize starch grain on pot from Kumi Kipa
Locus 6782, SS 362: a) Granule 1, TL (N1632), b) Granule 1, PL (N1631)

Identification of maize phytoliths

Most artifact residues were re-scanned for the presence of the narrow elongate rondel and the ruffle top rondel after the completion of the wild grass and maize study. Full results are reported in Appendix 2A. Only narrow elongate rondels were encountered on the artifacts; no ruffle tops were positively identified (Appendix 2A). Narrow elongate rondels diagnostic of maize were found on most manos sampled from Chiripa Quispe (Table 6.3; Figure 6.8). In some cases, these identifications were supported by starch grains identified as *Zea mays* or probable maize (Table 6.3; Appendix 2A). The presence of both phytoliths and starch grains indicative of maize lends support to the accuracy of

the phytolith method, and solidifies the claim for maize at Chiripa Quispe. In total, maize phytoliths were positively identified on five manos and one metate from Chiripa Quispe (Table 6.3) (Figure 6.8).

Table 6.3: Evidence for maize on TAP artifacts

Site	Locus	Artifact	Phytoliths	Starch
Chiripa Quispe	3109A	Mano	*Zea mays* (3), cf. *Z. mays* (5)	cf. *Zea mays* (1)
	3109B	Metate	*Z. mays* (7), cf. *Z. mays* (6)	None
	3110A	Mano	*Z. mays* (3), cf. *Z. mays* (10)	None
	3110B	Mano	*Z. mays* (1), cf. *Z. mays* (6)	Unidentified (1)
	3114	Mano	*Z. mays* (2), cf. *Z. mays* (1)	*Z. mays* (1)
	3132	Mano	*Z. mays* (2), cf. *Z. mays* (6)	*Z. mays* (2)
Kumi Kipa	6523	Incensario	*Z. mays* (2), cf. *Z. mays* (6)	None
	6561	Mano	cf. *Z. mays* (1)	None
	6782	Pot	*Z. mays* (1), cf. *Z. mays* (3)	*Z. mays* (1)
Sonaje	6090	Hoe	cf. *Z. mays* (1)	None
Kala Uyni	5268	Human teeth	cf. *Z. mays* (3)	*Z. mays* (1)
	5282	Human teeth	*Z. mays* (2), cf. *Z. mays* (1)	None

At Kumi Kipa, maize was definitively identified on a Tiwanaku 1 (Late Formative) ceramic vessel and a Tiwanaku 4/5 *incensario*. Probable maize phytoliths were encountered on a mano. At Sonaje, only one probably maize phytolith was encountered on a large stone hoe. Finally, two mandibles from Kala Uyni both had evidence for maize, in the form of starch (Locus 5268) and phytoliths (Locus 5282). Interestingly, diagnostic narrow elongate rondels from teeth in Locus 5282 were still articulated in tissue (Figure 6.8i). Examples of maize phytoliths identified on artifacts are pictured in Figure 6.8.

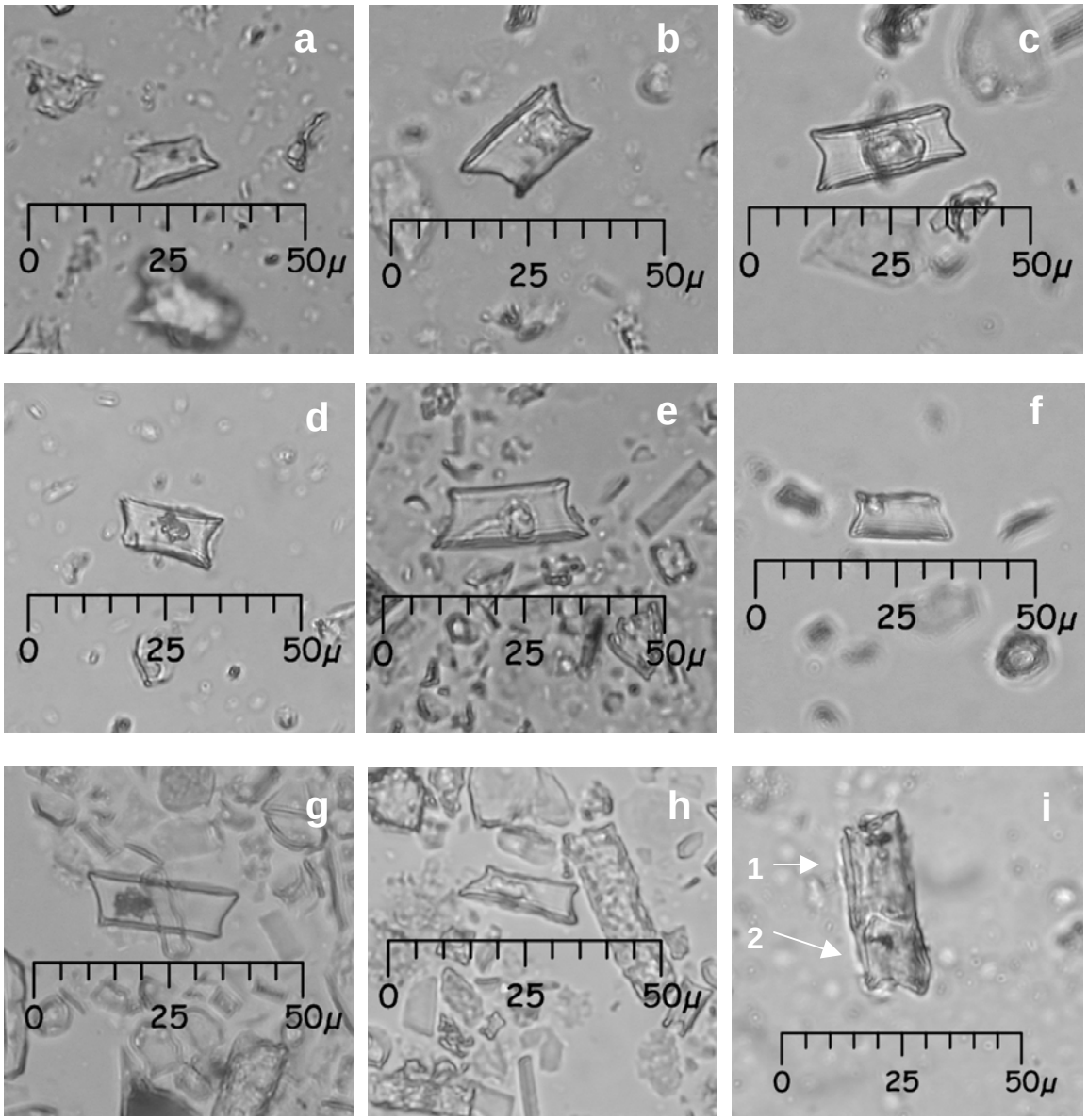
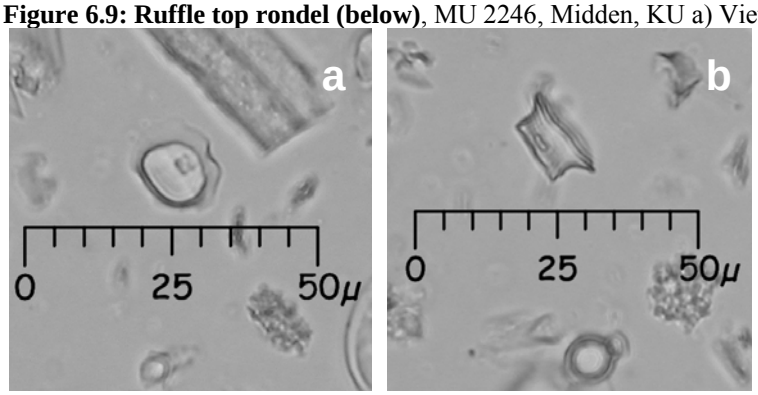


Figure 6.8:Examples of narrow elongate rondels from archaeological artifact residue samples (above) a) MU 2291, Mano, CQ (N1463), b) MU 2291, Mano, CQ (N1467) , c) MU 2360, Vasija, KK (N1473) d) MU 2309, Mano, CQ (N1476), e) MU 2356, Mano, CQ (N1491), f) MU2370, Mano, CQ (N1496); g) MU 2358, Metate, CQ (N1503); h) MU 2358, Metate, CQ (N1507); i) MU 2306, Human teeth, KU/AC (N1627), note that there are two narrow elongate rondels in tissue

Figure 6.9: Ruffle top rondel (below), MU 2246, Midden, KU a) View from top; b) View from side



Soil Samples

Soil samples were also re-examined for maize diagnostics after the development of the method. In general, it was more difficult to distinguish the narrow elongate rondel in soil samples, so identifications are very conservative. In other words, stricter identification criteria were employed when identifying maize in soil samples. This is due to the fact that rondel forms in general are the single most abundant type of phytoliths in soil samples overall (Appendices 2E-F).

As stated previously, no soil samples were analyzed from Chiripa Quispe; instead, analysis focused on Kala Uyni for reasons discussed in Chapters 3 and 5. Maize was positively identified at Kala Uyni in one sample from an area AQ midden, based on the presence of both a ruffle top (Figure 6.9) and narrow elongate (Figure 6.10a) rondel. Maize was also identified in eight soil samples from sunken court contexts in area AC (Loci 5018, 5020, 5111, 5112, 5184, 5233, 5325, 5380), as well as several samples in an unknown use structure at area KU (Loci 5154, 5164, 5318, 5358) (Figure 6.10) (Appendix 2A).

The presence of maize in 13 samples (out of 20 analyzed) suggests a fairly strong maize signature at Kala Uyni, especially in area AC. This is supported by maize on human teeth from two skeletons, in areas AC and KU. Likewise, the evidence also shows a strong maize signature at Chiripa Quispe. Evidence from Kumi Kipa is less strong, and there is no evidence for maize at Sonaje, however this may be due to the lower number of samples analyzed for these sites.

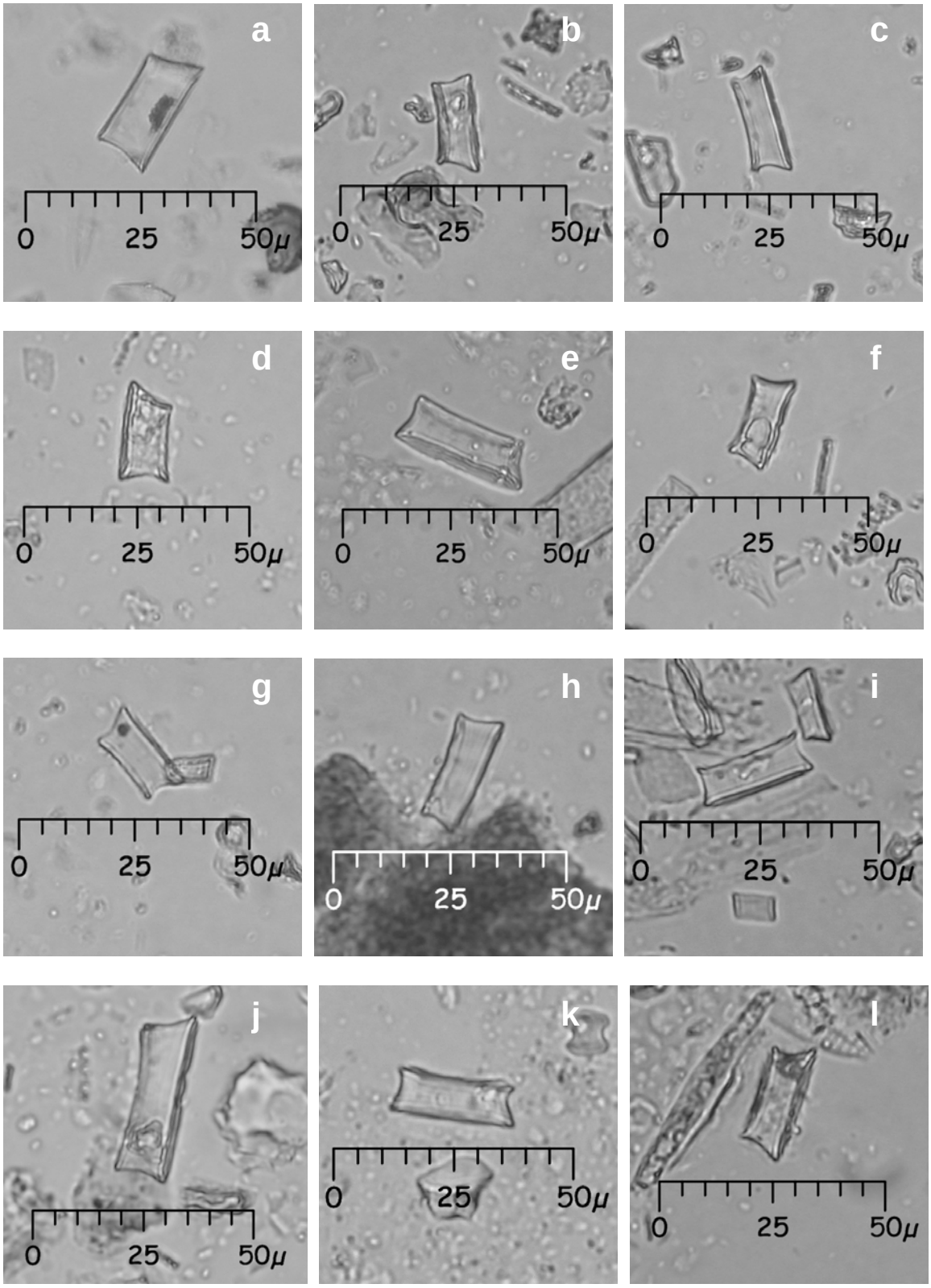


Figure 6.10: Examples of narrow elongate rondels from archaeological soil samples
a) MU 2246, Midden, KU (N1510); b) MU 2242 (N1517); c) MU 2243 (N1520); d) MU 2244 (N1539); e) MU 2245 (N1540); f) MU 2247 (N1543); g) MU 2248 (N1545); h) MU 2250 (N1546); i) MU 2202 (N1621); j) MU 2206 (N1625); k) MU 2205 (N1623); l) MU 2200 (N1630)

CHAPTER SUMMARY

While maize is perhaps the best studied plant archaeologically in South America, evidence for its dispersal throughout the Andean region in early periods is sparse. Maize formed a large component of macrobotanical assemblages at Tiwanaku, and was most likely obtained through trade rather than local production. However, it is unclear how far back this pattern extends, as macrobotanical remains of maize in the Formative period are very rare. Phytolith analysis excels at tracing maize, as diagnostics exist for both leaf and cob material, but these methods have not been tested for use in high elevation festucoid dominated grasslands. Phytolith production was documented in all wild grass genera of highland Bolivia and Ecuador to address potential overlap with established maize diagnostics, explore the potential of an assemblage based method, and delimit new diagnostics for this region. Considerable overlap existed between the wavy top rondel found in maize and forms in wild grasses, but the ruffle top rondel appears to be unique to maize. Three simple ratios were devised that clearly separated maize comparative samples from wild grass comparative samples. However, when tested on a small number of test soil samples known to contain or not contain maize, results were problematic. Multivariate analyses encountered similar problems were encountered. Namely, while it is possible to separate 'pure' comparative grass assemblages from maize, discriminating maize in a 'mixed' soil assemblage is difficult to impossible. However, a new diagnostic for this region, the narrow elongate rondel, was defined. TAP samples were subsequently rescanned, and strong maize signatures were found at Chiripa Quispe and Kala Uyni, suggesting that this crop played an important role. Evidence for maize was rare at Kumi Kipa, and no maize phytoliths were encountered at Sonaje.

CHAPTER 7
DISCUSSION

INTRODUCTION

The primary objectives of this thesis are to evaluate the potential of microfossil analysis in the highland Andes, and use both phytolith and starch grain evidence to discuss the role of subsistence, exotic, ritual, and trade plants in the development of multi-community polities on the Taraco Peninsula during the Formative period. Unfortunately, two major avenues of this research, concerning Andean tubers and hallucinogens, were not productive. Evidence for exotic plants, including maize and general tropical indicators, is suggestive of prehistoric trade links that extend beyond the Lake Titicaca basin.

These results raise several issues. First, given that the central Andes is thought to be the homeland of domesticated potato, oca, ullucu, and mashua, why do we find no starch evidence of these important crops at TAP sites? Second, does the negative evidence for hallucinogens speak to archaeological reality or is this a function of context and taphonomy? Third, what is the role of exotic plants at TAP sites? Finally, what is the status of maize identification using phytolith analysis in the highland Andes, and what does the presence of maize during the Formative period imply?

These issues are considered in regards to the potential of phytolith and starch grain analysis for explicating social and economic processes in the highland Andes. As one of the few microfossil studies that focuses on this region, it is important to address several outstanding questions about the usefulness of these specialized techniques.

WHERE HAVE ALL THE TUBERS GONE?

As discussed extensively in Chapter 4, no evidence was found for Andean tubers on the Taraco Peninsula. None of the taxa produce diagnostic phytoliths, but the use of starch grain analysis was thought to have excellent potential. Nonetheless, evidence is limited to only a single probable tuber starch grain discovered on one TAP artifact. Three explanations may account for these observations: 1) taphonomic constraints are negatively affecting the survivability of tuber starch, 2) none of the artifact types sampled came into contact with tubers, and/or 3) tubers were not present during these periods or at the sites sampled.

Research on starch grain taphonomy is only just beginning (*e.g.* Chandler-Ezell *et al.* in press; Pearsall *et al.* 2005; Zarillo 2005). Starch grain studies in South America almost uniformly uncover maize starch, with starch of roots and tubers present rarely, in small quantities, or absent entirely (Zarillo 2005). Given the early evidence for cultivation of lowland root and tuber crops using phytolith analysis (Pearsall 1992; Piperno and Pearsall 1998b), it is surprising that the majority of remains recovered are that of maize. Perry *et al.* (2006) is perhaps the best example of this—maize starch is recovered in enormous amounts (over 1000 granules) from both soil and artifact samples; evidence for tubers (cf. *Solanum* sp.) is limited to three starch grains on one tool. This makes little sense in light of the location of the site examined, in highland Peru, not dissimilar to highland Bolivia.

These observations suggest that there is more to the story then that maize simply dominates most South American sites examined thus far. One possibility is that because Andean tuber grains are typically large and ovate (see Figure 4.2), they are more likely to

fall prey to breakage through food processing. In the highland Andes, tubers are often freeze-dried (to increase storability). Experimental studies by Babot (2003) demonstrate that this process is quite destructive to starch grains. Dehydration, ice crystal growth, as well as mechanical destruction (by stomping on the tubers) tend to severely damage starch. Grains often show flat relief, lack or have highly obscured extinction crosses, burst, or are fragmented, significantly decreasing the chances of survival and identification. Interestingly, these destructive processes seem to affect large starch grains more than small ones (Babot 2003). The presence of *chuño* on the Copacabana peninsula during Yaya-Mama (Middle/Late Formative) periods (Lee 1997) hints that this technology had already been developed at this time. In addition, freeze-dried tubers are usually boiled before consumption. Boiling, because it involves high, moist heat, has disastrous effects on even the most hardy starch grains[17] (Chandler-Ezell *et al.* in press; Pearsall *et al.* 2005). The combination of both types of processing would significantly reduce the probability of starch survival, and may account for the general absence of tuber starch grains on artifacts sampled in this study.

One of the best indications that taphonomic or contextual factors are responsible for the paucity of tuber starch grains is that no grains were recovered from Tiwanaku 4/5 period artifacts. Andean tubers are confirmed in the area by Tiwanaku 4/5 times by macrobotanical evidence (Wright *et al.* 2003), therefore if these starch grains are recoverable, one would expect their presence at minimum on Tiwanaku 4/5 artifacts. Tiwanaku 4/5 artifacts sampled included a ceramic *incensario*, human teeth, manos, and llama mandible scrapers (Appendices 2A-B).

[17] Although boiling temperatures at higher elevations are lower (1º C lower per 1000 ft = about 88ºC for Taraco Peninsula), they are still above gelatinization temperatures of most starch grains [*e.g.* maize = 63-68º C; potato = 65-67ºC (Reichert 1913)].

Another possibility is contextual in nature—it is quite possible that the artifact types sampled were not used for any tuber processing, cooking, or consumption activities, but for other uses altogether. This is certainly true with some of the artifact types targeted for other reasons, such as tracking hallucinogens (*i.e.* ceramic trumpet fragments, crucibles). While manos are metates are multi-purpose tools, they may have had little contact with Andean tubers, and instead showed evidence of maize. However, the only Andean tuber starch recovered by Perry *et al.* (2006) was on a single groundstone, suggesting that sampling these artifacts is not a bad strategy. With this in mind, it is important to point out that a wide range of artifact types was sampled considering these constraints. In fact, all major (and some minor) artifact classes recovered at TAP sites were sampled, and none were productive, suggesting that there is instead some taphonomic issue unique to tuber starch preventing its survivability.

Other avenues of investigation may be more profitable in regards to tuber starch recovery. Extraction of starch grains directly from soils may be a better tactic, although it is important to note that Perry *et al.* (2006) did not recovery any tuber starch from the soil—their tuber grains were confined to a single groundstone fragment. One final possibility is the extraction of starch grains from charred pot residues. As Wright *et al.* (2003) suggest, differential cooking methods such as boiling may account for the low survivability of tuber macroremains; the same may be true of starch. Boiling is extremely hard on starch grains, and if tubers were also freeze dried, the effects are exponentially increased, as discussed above. From this vantage, pot residues may also be problematic contexts for starch recovery.

The nature of these results beg the question as to when and where Andean tubers were first domesticated and/or brought under cultivation. Unfortunately, because none of the tubers of interest produce diagnostic phytoliths, and starch preservation seems to be severely compromised, it is unlikely that this issue will be resolved in the near future.

EXOTIC PLANTS AND TRADE

Comparative studies focused on documenting phytolith production in 12 hallucinogens; diagnostic phytolith forms were delimited in three of these—*Anadenanthera*, *Banisteriopsis*, and *Datura*. Both artifact residue and archaeological soil samples from a wide variety of contexts were examined for hallucinogenic plants, but none were productive. There are three possible explanations for this observation, not dissimilar to the tuber issue discussed above. First, it may be that the use of hallucinogens does not develop until after the Formative period. The use of psychoactive plants is clear in Tiwanaku contexts (Torres 1995; Wassen 1972), but evidence is lacking for earlier periods in this region. Second, diagnostics were only discovered in three hallucinogens, and only in specific parts of the plant. These particular genera (*Anadenanthera*, *Banisteriopsis*, and *Datura*) may not have been the hallucinogens of choice during the Formative period. Alternatively, because these may have been highly valuable commodities, it is possible that only the plant part used was traded in. This complicates the search for evidence of hallucinogens, because diagnostics were delimited only in certain plant parts, and were usually rare. *Anadenanthera* diagnostics were contained in the pod, while the seed is what is usually used for snuff. Diagnostic phytoliths in *Banisteriopsis* were located in the leaf, which is occasionally used added to fermented beverages, but it is the bark that is primarily used for hallucinogenic effect. *Datura*

diagnostics were also located in the leaf, however the leaf, as well as the seeds and roots, is often used.

Evidence for other exotic plants was ambiguous, despite ample documentation of phytolith production in tropical plants (*i.e.* Pearsall *et al.* 2006; Piperno 2005). Nodular spheres, representative of Marantaceae, Zingiberales, or Bombacaceae, as well as a spinulose sphere typically of Arecaceae, were uncovered in several archaeological samples. Each of these families enjoys tropical distribution, and lacks local representatives in the highlands. Nodular spheres in highland contexts are probably less likely to represent Bombacaceae, which is a tropical lowland family that mostly comprises arboreal species, and lacks any economically important representatives. It is more likely that the spheres represent Zingiberales or Marantaceae, as both families contain valuable economic plants, achira (*Canna edulis*) and arrowroot (*Maranta arundinacea),* respectively. Additional phytolith diagnostics do exist for both taxa, but were not encountered in archaeological samples. However, discovery of arrowroot at Waynuna, a highland Peruvian site dating to 3600-4000 bp (Perry *et al.* 2006), suggests that this taxon was certainly known in highland contexts during the Formative period. Perry *et al.* (2006) further suggest that arrowroot arrived in the highlands from the Amazon in the east, rather than coastal Peru. A similar argument might be made for TAP spheres, if they represent Marantaceae; future research may help clarify these identifications.

A single palm sphere was also encountered. Ethnographically, the importation and use of *chonta* palm for production of implements such as the foot plow in the altiplano is well known (Hastorf pers. comm. 2006). Wood is a relatively rare resource on the modern

altiplano, where eucalyptus (an introduced species) is the primary source of wood. Oddly, the palm sphere was encountered on a mano from Chiripa, raising the possibility that it may have been palm fruits that were imported instead of wood.

A variety of hair cell bases with unknown taxonomic affinity were also encountered that may indicate tropical plants. Taken together, the small and isolated presence of exotic plants in TAP samples suggests some trade in these plants, although at this point the phytolith evidence is too sparse to suggest intensive trade links with lowland Amazonian regions. At this point, it does seem safe to say that exotic plants were present at TAP sites during the Middle to Late Formative period in small amounts, although their precise meaning is unclear at present.

THE MAIZE ISSUE

The identification of maize during the Formative period on the Taraco Peninsula raises several questions surrounding methodology, and provides some of the earliest evidence for this important crop in this region.

Methodological Implications

The initial objective of the maize and wild grass study was to establish baseline data on the grasses of the highland Andes, address any possible confusers for maize inflorescence diagnostics, and explore the potential of a statistical, assemblage based approach to discriminate between maize and wild grass signatures. Because all wild grass genera of this region were considered, this approach has the added benefit of being able to distinguish several diagnostic short cells across many genera.

However, because confusers for maize diagnostics used in the lowlands were found amongst the wild grass taxa, one conclusion is that wavy top rondels cannot be

used to identify maize in this region. Ruffle top rondels are a stronger type, and with caution, it is possible to separate out maize from wild forms. However, one must stick very closely to the type definition—slight variations in this type overlap with wild grasses. Overall, only one securely identified ruffle top rondel was identified in TAP samples. Instead, several probable ruffle top rondels were recognized, but given the margin of potential overlap, they could not be definitively assigned to maize or wild grasses.

To counter these issues, an assemblage-based approach was explored. The approach relied upon a typology constructed specifically for the highland Andes, and count data for each of the types. Use of simple ratios and multivariate techniques were for the most part able to successfully discriminate between maize and wild grass comparative samples. However, problems were encountered when each method was applied to test soil and artifact residue samples. None of the techniques discriminated between samples that contained maize from those that did not.

The main reason for this observation is that counts on grass comparative samples represent the species in its pure, concentrated form. Archaeological samples, on the other hand, contain a very large and diverse collection of background grass types. Therefore, even if maize is present in a particular sample, the signature will be heavily obscured by wild grass short cells, which are present in every TAP sample. This problem becomes severe when maize is expected to occur rarely or in small amounts.

Fortunately, a new diagnostic type for maize was discovered, the narrow elongate rondel. The narrow elongate rondel can be separated from all wild grasses examined in this study. It is also produced abundantly in maize comparative samples, in greater

numbers than ruffle top rondels. Use of both types, as well as starch grain analysis, significantly improves the chances and accuracy of identifying maize in the Andean highlands, especially where maize is expected to occur rarely.

This leads to two major observations. Assemblage-based methods focusing on the Andean highlands, including those targeting artifact residues, need to find a way to disentangle the presence of maize amidst a sea of wild grasses. One possible suggestion on this front is the development of a 'background correction factor', whereby one can accurately assess the percentage of the sample that is background or wild grass, and correct or remove the 'background' effect from soil samples. This may prove very difficult due to the absolute ubiquity of wild grass phytoliths in every soil (and artifact) sample analyzed. Instead, use of diagnostic phytoliths and/or starch grains may prove to be a more reliable means of identifying maize in the Andean highlands (*e.g.* Perry *et al.* 2006), especially in contexts where it is expected to be rare.

The second issue to arise concerns previous studies that employ assemblage-based approaches for the identification of maize. The most relevant of these are Chávez and Thompson (2006), Hart *et al.* (2003) and Staller and Thompson (2002), who use an assemblage based method that relies on rondel forms in maize to distinguish maize varieties in pot residues. As mentioned in Chapter 6, the analyst for these studies (Thompson) relies on the assumption that within a pot, maize residues will be concentrated, therefore one can establish the variety of maize present based on varying proportions of various rondels. Thompson uses statistical techniques (squared-chord distance and detrended correspondence analysis) to classify residue assemblages as maize

or otherwise, and importantly, does not quantitatively consider wild grass rondel forms[18]. Many festucoid dominated grasslands, including New York (Hart *et al.* 2003), contain several of the wild grass genera analyzed in this study. Chávez and Thompson (2006) report on results from the Copacabana Peninsula, just across the lake from TAP sites and within a similar ecotone (Figure 2.3). If nothing else, the present study speaks to the tremendous variety of rondel assemblages in wild festucoid grasses, many of which overlap significantly with maize morphologically, metrically, and even on the assemblage level. Because soil particles are often mixed inadvertently in artifact residues, including pot residues, it is highly likely that wild grass phytoliths are also incorporated into pot residue samples. In addition, wild grasses such as *Festuca* spp., may have been used as food, and cooked in pots or ground on manos, especially in early prehistory (*e.g.* Lee 1997; Pearsall 1989).

The second issue with Thompson's method is analytical in nature. From his published analyses, it appears that he compares archaeological assemblages directly to modern maize assemblages. This is problematic on three fronts: 1) taphonomic issues derived from the process of cooking may alter archaeological pot residue assemblages (Pearsall *et al.* 2006), 2) sample sizes are very small, generally compromising analysis of four pot sherd residues, and 3) the null hypothesis (*i.e.* no maize) is not adequately tested. By comparing archaeological assemblages only to maize assemblages, and not to wild grass assemblages, there exists a significant possibility of false positive identifications. Statistically, assemblages can appear to be related depending for instance, on the number

[18] It may indeed be that Thompson has investigated assemblages from wild grasses and compared them statistically to maize; however, as his method has never been fully published, and he never mentions comparison of archaeological assemblages to wild grass assemblages, and does not present his raw data, I assume here that he does not consider wild grass assemblages adequately.

of clusters desired by the analyst. In other words, statistical applications are no more objective than any other techniques; rather, there is still considerable room for subjective bias. As presented in Chapter 6, wild grass assemblages, especially combinations of different wild grasses likely to be found in soils, mimics maize assemblages, even when multivariate methods are employed.

It should be noted that Chávez and Thompson (2006), which was published after completion of this analysis, do describe methods in more detail than previous publications. Of importance here is that for the first time, Thompson explains how rondels are characterized morphometrically. One of the characters measured is length and width of rondels. It may be that the diagnostic defined in the present study, the narrow elongate rondel, is recognized through these measurements, and may be the distinguishing element in his assemblage-based approach. This is difficult to evaluate, however, as raw data are not presented.

Based on these observations, I strongly urge phytolith analysts using an assemblage based approach to more fully characterize wild grass taxa native to the study region in order to search for maize confusers, as well as use an independent confirmatory technique, such as starch grain analysis (*e.g.* Perry *et al.* 2006). While this approach has been extensively employed by researchers using the 'diagnostic approach' (*e.g.* Pearsall 1979; Pearsall and Piperno 1990), and some using an 'assemblage-based approach' (*e.g.* Mulholland 1993), it is critical that all researchers regardless of approach take wild grass data into consideration. The present study attests to the complexity of disentangling which grass (maize or wild) has contributed to the assemblage of interest, whether an artifact residue or archaeological soil sample.

Context and Interpretation

Using the new maize diagnostic developed in this study, maize was identified in Formative period contexts from the Taraco Peninsula, raising several interpretive issues. While maize cultivation is possible on a small scale in areas near the lake on the Taraco Peninsula, it is unclear if the crop was cultivated in the region during the Formative period. Archaeobotanical evidence from later Tiwanaku, located much farther inland in areas unable to support maize cultivation, suggests that maize was traded in on a large scale (Hastorf *et al.* 2006). Given this evidence, phytolith and starch data was used to evaluate whether or not maize was cultivated locally or imported from other regions into the Taraco region during the Formative period. Because diagnostic phytoliths are produced in both leaf and cob material, it should be possible to trace both the primary product (kernels/cobs) and byproduct (leaf) material in the archaeological record. An absence of leaf material, but presence of cob material would suggest that maize was not produced locally but instead imported.

Phytolith and starch evidence for maize kernel and cob material was uncovered on six manos, two ceramic vessels, human teeth from two burials, and thirteen soil samples from three sites in total. No large or extra-large cross bodies diagnostic of maize leaf (Pearsall and Piperno 1990) were encountered in any of the samples analyzed. However, it has been noted previously by Perry *et al.* (2006), some Andean maize varieties do not seem to produce large or extra large cross bodies, preventing definitive identification of maize leaf material. Other phytolith forms found in maize leaf (small and medium crosses, large bilobates) were present occasionally in TAP samples, but are also produced in some local wild panicoid grasses and cannot be considered unique to maize. However,

while the presence of crosses and bilobates in isolation cannot be used to attest to the presence of maize leaf, one would expect that if maize leaf was present in a particular context, the numbers of these phytolith forms would be elevated. This pattern has been observed in some soil samples from Kala Uyni, but it is difficult to rule out whether it is indicative of the contribution of wild panicoid or maize leaf material.

One other complicating factor is contextual in nature. Maize leaves are unlikely to be encountered in contexts like artifact residues or floors. Leaf (byproduct) material would not have been in much contact with grinding stones, however, one would expect to find leaf phytoliths in discard areas like middens or perhaps floors. However, there does not seem to be any very dense accumulation of small to medium crosses or large bilobates in middens or floors at Kala Uyni. If, as suggested below, maize is associated with special purpose events like feasts, it is likely that initial processing of maize (*i.e.* shucking) took place further afield, perhaps in individual farmer households. The areas sampled instead appear to be locations where maize was likely cooked or consumed. This explanation, in conjunction with lack of large cross production in Andean maize, can at least partly account for the lack of evidence for maize leaf material. Based on this evidence, it is difficult at this point to rule out either local cultivation or importation of maize.

Another outstanding issue relating to the local production of maize concerns climate change during the Formative and subsequent periods. Paleoclimatic studies from Quelcayya ice cores (Thompson *et al.* 1985) and cores from Lake Winaymarka (Abbott *et al.* 1997) suggest alternation of arid and humid phases during the Late Holocene. In the Lake Titicaca basin, these fluctuations have dramatic effect on lake levels. Since Lake Titicaca is rather shallow, even a small decrease in lake depth exposes large expanses of

ground surface. It has been argued that humid periods, causing a rise in lake levels, coincide with both the emergence of agriculture at Chiripa around 1500 BC, and the development of the Tiwanaku state around AD 500. Concomitantly, an arid phase seems to be associated with the subsequent fall of Tiwanaku around AD 1100 (Binford *et al.* 1997; Ortloff and Kolata 1993). High lake levels during humid periods apparently allowed for the construction of raised field features during Tiwanaku 4/5 times, while a subsequent period of aridity and lowering lake levels resulted in the failure of raised field agriculture and fall of Tiwanaku around AD 1100 (Binford *et al.* 1997). Other have challenged this view, suggesting that low lake levels exposed massive amounts of wet, fertile land, instead encouraging increased agricultural production (Erickson 1999). However, severe retreat of the lake also decreases the total heat capacity of the surrounding fields. Current (high) lake levels create microclimatic zones around the lake edges that stabilize near ground temperatures, helping to prevent overnight frosts (Binford *et al.* 1997.;Kolata and Ortloff 1996).

While raised field agriculture probably did not become widespread until Tiwanaku times, climate change and particularly, lake level fluctuations, may have had a significant impact on local populations on the Taraco Peninsula. Low or high lake level stands may have especially influenced the production of maize on lake edges. Maize is not suited to conditions on the altiplano, except in select microclimates around lake edges. This is in part because maize is particularly sensitive to the number of frost-free days, aridity, and altitude. As suggested above, high lake levels act to increase the number of frost-free days, and correspond with humid conditions. These conditions would act to increase the maize growing potential of areas near the lake edges.

Figure 7.1: Lake Level Fluctuations at Lake Titicaca

Date	Titicaca Basin	Taraco Peninsula	Lake Level
1500 AD	LATE HORIZON	LATE PACAJES	HIGH
	ALTIPLANO	EARLY PACAJES	HIGH
			LOW
1000 AD	MIDDLE HORIZON	TIWANAKU 4/5	HIGH
500 AD			
	LATE FORMATIVE	TIWANAKU 3	
		TIWANAKU 1B	LOW
BC/AD		TIWANAKU 1A	HIGH
	MIDDLE FORMATIVE	LATE CHIRIPA 2	LOW
500 BC		LATE CHIRIPA 1	HIGH
	EARLY FORMATIVE	MIDDLE CHIRIPA	LOW
1000 BC		EARLY CHIRIPA	HIGH
1500 BC			

From Abbott *et al*. 1997; Binford *et al.* 1997; Bandy *et al.* 2004

Chronologically, humid periods and corresponding high lake level stands occur during the Late Chiripa 1 phase, Tiwanaku 1A, Tiwanaku 3, and Tiwanaku 4/5 phases (Figure 7.1). During these periods, one would expect that maize cultivation was more likely, or at very least, more productive, than in arid, low lake level periods. While available dates are limited, phytolith and starch evidence for maize on the Taraco Peninsula seems to coincide with these periods, occurring in Late Chiripa contexts at the site of Chiripa-Quispe, and in Tiwanaku 1 times at Kala Uyni and possibly Kumi Kipa. Maize macroremains are also common at Tiwanaku Valley sites during Tiwanaku 4/5 times (Wright *et al.* 2003). Recent analysis suggests that maize was traded into Tiwanaku from other areas, such as Cochabamba and Moquegua (Hastorf *et al.* 2006).

Phytolith and starch evidence for maize suggests the presence of cob material, and a paucity of maize leaf material at Taraco Peninsula sites. However, given that climatic conditions were favorable for maize production around the lake edges during Late

Chiripa and Tiwanaku 1 times, one cannot exclude the possibility that maize was cultivated on the peninsula. Maize does grow in isolated regions around the lake today, and probably did in the past, although likely was not as productive as in other lowland regions. Consumption of maize during the Formative period seems to have occurred on a small scale, as there are no maize macroremains from the Taraco Peninsula during this period, and microremain evidence occurs in limited contexts. Therefore low level production of maize near the lake may have been sufficient to meet demands during the Formative period. Local lake side production was likely not sufficient however to meet demands during Tiwanaku 4/5 times, and it is at this time there is evidence that maize is being traded in from lower altitudinal zones (Hastorf *et al.* 2006). It is possible that some of this maize may have derived from the Taraco Peninsula, although the absence of maize macroremains from these sites precludes metrical comparison to the Tiwanaku maize assemblage. In fact, the emergence of raised field cultivation would have been ideal for maize production in this area, and may have been part of agricultural intensification during Tiwanaku times (Hastorf pers. comm. 2006).

Maize is far from ubiquitous in Formative period contexts in the southern Lake Titicaca basin. Macrobotanical evidence is limited to one kernel and one cupule, and four pot sherds on the Copacabana Peninsula (Chávez and Thompson 2006; Lee 1997), with no maize macroremains recovered at Chiripa (Whitehead 1999b). However, phytolith and starch grain evidence from the Taraco Peninsula suggests the occurrence of maize in selected contexts at Chiripa, Kala Uyni, and Kumi Kipa. Maize was uncovered on four types of artifacts, grinding stones, a Tiwanaku 4/5 *incensario*, a Late Formative ceramic vessel, and human teeth. Maize was recovered from soil samples at the site of Kala Uyni.

These finds suggest that maize was far from common during Formative period times; rather, it was prepared and used in restricted contexts.

At Chiripa, maize was uncovered on six grinding stones associated with an early Late Chiripa (Quispe) enclosure dating to 900-400 BC, among the earliest evidence for the crop in the Lake Titicaca region. Importantly, the Quispe enclosure is in close proximity to ritual sectors of the site, and it has been suggested that it served as a food preparation area for special purpose meals or feasts (La Paz Soria 1999). While no soil samples were analyzed from Chiripa, the presence of maize on manos and metate fragments from this context suggests that maize was probably being prepared for special events or feasts.

At Kala Uyni, maize was uncovered in selected soil samples from three sectors of the site, including the Late Chiripa sunken courts at the top of the hill (AC), a non-domestic Tiwanaku 1 stone structure (KU), and one sample from a Late Chiripa domestic midden (AQ) (Bandy *et al.* 2004). No grinding stones were analyzed from this site, making a direct comparison to the Chiripa materials difficult. The spatial spread of maize finds in the ceremonial core (AC), comprised of two sunken trapezoidal enclosures and associated middens, is also instructive (Table 7.1). Maize appears in both the Lower and Upper Courts, although it appears to be more prevalent in the Lower Court. Floors are particularly productive for maize, but especially near the structure walls. This may be related to use or discard patterns, such cleaning or sweeping refuse towards the wall edges. Maize appears throughout KU, and in one domestic midden sample (AQ), although no obvious contextual patterns were encountered.

Table 7.1: Comparison of Kala Uyni Contexts with and without Maize (AC Only)

Site	Unit/Locus	Context
Samples containing Maize		
AC	N968 E921, Locus 5018	Lower Court: Upper Floor
	N968 E921, Locus 5020	Lower Court: Lower Floor
	N962 E928, Locus 5111	Lower Court: Southern unit, floor, well preserved, lots of carbon
	N962 E928, Locus 5112	Lower Court: Southern unit, floor, well preserved, lots of carbon
	N980.4 E928.18, L.5184	Lower Court: Northern unit, a sloping floor
	N990 E968, Locus 5233	Upper Court: Midden below rocks associated with court
	N982 E955, Locus 5325	Upper Court: Floor
	N975 E917, Locus 5380	Lower Court: Eastern unit, floor
Samples with NO Maize		
AC	N968 E921, Locus 5017	Lower Court: fill layer beneath floor
	N979 E957, Locus 5238	Midden near Upper Court
	N975 E917, Locus 5294	Lower Court: Eastern unit; floor, or fill between floors
	N993 E952.5, L.5343	Upper floor of Upper Court
	N993 E952.5, L.5345	Lower floor of Upper Court

Context data from Bandy *et al.* (2004), and personal communication with A. Cohen and A. Roddick in 2003. Additional maize finds occurred in other areas of the site (KU and AQ), but are not illustrated here. Please see Appendix 2D for data from all samples.

Furthermore, maize was recovered from human teeth from two burials, one in the KU sector (Locus 5268), and another in the AC sector (Locus 5282). It was suggested that the burial at AC is a ceremonial dedicatory offering of sorts, as it is buried underneath one of the walls of the lower sunken court (Roddick and Cohen in Bandy *et al*. 2004). Kala Uyni is thought to be an important center on the peninsula during the Late Formative period, perhaps exercising political dominance over the region (Bandy 2004). The presence of two sunken courts atop the main hill also suggests that it had an important role in public ceremonialism in the region. The presence of maize in several contexts at this site is not surprising, although why it is there remains open to speculation. However given the association of maize with special purpose contexts early on at Chiripa, it may be that maize at Kala Uyni is similarly associated with special events. Indeed, evidence of maize is prevalent in sunken court floor contexts, as well as in burials associated with the site, further suggesting its association with ritual activities.

At Kumi Kipa, few Formative period contexts were encountered. One exception was an unknown use structure, from which one nearly complete Late Formative pottery vessel that is reminiscent of later *incensarios* was sampled[19], and later found to contain maize. Interestingly, a Tiwanaku 4/5 *incensario* from a burial at the same site also contained maize phytoliths. Grinding stones from Kumi Kipa were also sampled, but no evidence for maize was encountered. Here maize use also appears to be limited, not to domestic objects or contexts like grinding stones, but to an *incensario* and similar vessel that are arguably associated with ritual activities, including burial practices. Although meager evidence, the appearance of maize in an incensario-like Formative period vessel, as well as a Tiwanaku 4/5 period *incensario*, as well as its presence on human teeth from two burials at Kala Uyni, suggests that at least one element of later Tiwanaku, the association of maize with ritual and death, and perhaps ancestor cults (Hastorf 2003), was already being formulated.

While admittedly few domestic contexts have been sampled, the evidence presented above does suggest that maize was relatively rare on the Formative period Taraco Peninsula, and probably limited to special purpose contexts. Evidence from the Copacabana Peninsula, as well as the data presented here, seem to indicate that the arrival of maize in the Lake Titicaca basin coincides with the emergence of the Yaya-Mama Religious Tradition. As the phytolith and starch data presented here falls within the earliest time frame for maize in this region, it has implications for understanding the nature of the spread of maize in the Andes. Future applications of the phytolith diagnostic developed in this study elsewhere in the Andes may help address this issue.

[19] I may be completely mistaken here in comparing the Tiwanaku 1 vessel to *incensarios.*

CHAPTER 8
CONCLUSION: THE POTENTIAL OF MICROFOSSIL ANALYSIS IN THE ANDEAN HIGHLANDS

This study focused on the application of phytolith and starch grain analysis to understanding subsistence, trade, and ritual in the Formative period in highland Bolivia. The initial objective was to use microfossil data to address three models that may explain the development of the Tiwanaku state, in conjunction with the wider goals of the Taraco Archaeological Project. However, differential phytolith production in many plant species of interest, as well as preservation and taphonomic issues concerning both starch grains and phytoliths has precluded full realization of this goal. Like most pilot studies focused on a specific region, this research instead had to focus on resolving various methodological issues and establishing baseline comparative plant data. However, this thesis has been left in the original, intended format, according to research question, to illustrate how phytolith and starch grain data may eventually contribute to major theoretical debates. If nothing else, this research may serve as an introductory guide to future microfossil studies in the highland Andes.

The first objective was to define the potential of using calcium oxalate crystals to identify plants archaeologically. A processing procedure was developed that isolated both calcium oxalate and silica from soil, with moderate success. Shape classes useful for identification were recognized. However, before archaeological applications of this microfossil can be realized, a thorough study of the production and taphonomy of calcium oxalate shape classes and quantities across plant families is required. At this juncture, calcium oxalate crystals may be useful as a secondary technique, that used in conjunction

with other types of archaeobotanical identification techniques, may serve to solidify or confirm identifications of certain plants.

The second objective concerned the development of diagnostic microfossil indicators of local subsistence plants, and determination of their role at TAP sites. Altiplano crop plants investigated included quinoa, potato, ullucu, mashua, and oca. None of these plants produced diagnostic phytoliths, suggesting that this type of analysis is not appropriate for getting at the cultivation of Andean tubers and quinoa. Instead, starch grain analysis was employed as a promising alternative. Refinement of identification criteria for separating starch grains of the different tubers is needed. Several different artifact classes were examined for starch, but only one tuber starch grain was uncovered. Taphonomic issues seem to be negatively affecting the survival of tuber starch grains. Future focus on identification criteria, isolation of starch grains from soil samples, as well as ethnoarchaeological studies targeted towards understanding root and tuber deposition and taphonomy may help alleviate the under-representation of these important crops in the archaeological record.

The third objective focused on defining phytolith indicators of important South American hallucinogenic plants, and tracing both hallucinogens and other exotic plants at TAP sites. Diagnostic phytoliths were defined for three hallucinogens (ayahuasca, vilca, and jimsonweed), but none were encountered in archaeological samples. A few exotic phytolith indicators from tropical lowland species were encountered in archaeological samples. These data suggest that tropical plants made only a small contribution at TAP sites. Future application of hallucinogen diagnostics to other sites throughout South America may prove useful, specifically when ritual paraphenilia is targeted. In addition,

the tropical lowlands have seen the most intensive phytolith research, and the application of these diagnostics to highlands sites has great potential, especially since the movement of plants and people between these regions is often cited as a major factor in culture change in the Andean region (*e.g.* Lathrap 1977). However, additional comparative work on Amazonian plants that were likely traded into the south central Andes is needed before the role of exotic and trade plants can be clearly evaluated.

Phytolith analysis also excels at tracing members of the grass family, particularly maize. The fourth objective concerned tracking the role of maize on the Taraco Peninsula during the Formative period. Phytolith identification methods developed for the lowland tropics were tested against the local wild grass flora. This study indicated that some types used in the lowlands, including the wavy top rondel, overlap significantly with wild festucoid grasses. Attempts were made to develop a multivariate assemblage based method for identification of maize, with little success. However, results indicate that maize can be identified in the highland Andes using 1) the ruffle top rondel, as defined for the tropical lowlands, and/or 2) the narrow elongate rondel, a new cob diagnostic discovered in this study, and/or 3) starch grains. Using this approach, maize was uncovered on artifacts from Chiripa Quispe and Kumi Kipa, and soil samples from Kala Uyni beginning in the Late Chiripa period (900-400 BC). This represents the first evidence for maize in the Titicaca basin, and suggests that its use was limited to restricted or special purpose contexts. This maize identification method is applicable to highland regions of Bolivia, Ecuador, and probably Peru, and will hopefully enjoy wide application in the future.

One other application of phytolith analysis is environmental in nature. Diatoms and wild plant indicators, such as sedge phytoliths, are fairly common in TAP samples. While beyond the scope of this study, further investigation of these forms may help elucidate specific environmental and lake level conditions. In addition, use of the wild grass typology developed in this thesis specifically for the highland Andes may identify changes in grassland composition and utilization. Because all native grass genera were examined for this region, a large number of diagnostic forms were established for different genera, and may prove useful in ecologically oriented studies.

An attempt was also made to broaden the application of artifact residue analysis to a diverse class of artifact types. The literature on artifact residues concentrates primarily on stone artifacts, especially manos and metates, and some ceramic residues (e.g. Hart *et al.* 2003; Loy *et al.* 1992; Pearsall *et al.* 2004; Piperno *et al.* 2000). Many of the artifact types sampled for TAP have not been reported in the residue literature, and, as such, are an interesting test case for microfossil residue analysis. In part, this study is an attempt to define the residues present or not present and taphonomic issues relating to these states for several different artifact classes (see photos in Appendix 2B). While not in any way exhaustive, it does appear that the traditional concentration of residue analysts on stone tools (*i.e.* manos, metates, flakes, etc.), and the recent attention devoted to pot residues (Chávez and Thompson 2006; Zarillo 2005), is in fact probably the most productive strategy.

Soil samples also contributed significantly to understanding the use of and potential roles of maize in TAP sites. Compared to artifact residues, which focus on only the plants processed on specific objects, soil samples are useful for gaining an

understanding of broader trends in and contexts of prehistoric plant use. Of particular relevance is the comparison of phytolith assemblage across archaeological contexts, which can at times be linked to certain types of human activities. Further analysis of soil samples of this region will help define the contexts of maize and possibly hallucinogen use (*i.e.* ceremonial, domestic). Isolation of starch grains directly from soil samples may also prove productive.

This study has raised several broad methodological issues related to the recovery of starch grains, differential phytolith production in many species of interest, and the identification of maize in festucoid dominated grasslands. While results of many of the avenues of investigation were negative, these issues are common constraints in microfossil studies. The lack of experimental and/or ethnoarchaeological models about phytolith and starch grain deposition and taphonomy severely constrains interpretation and results of many microfossil studies, a problem that will hopefully be remedied in the years to come.

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APPENDIX 1: PROCEDURES DEVELOPED

A. Modified Processing Procedure For Extracting Calcium Oxalate and Phytoliths

B. Field Procedure for Sampling Artifacts for Phytolith and Starch Grain Analysis

APPENDIX 1A:

Modified Processing Procedure For Extracting Calcium Oxalate and Phytoliths

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All samples centrifuged at 2000 rpm for 2 minutes unless noted otherwise. Procedure is modified from Pearsall (2000: 424-431), and is designed for an eight sample set.

Initial Preparation

1. Dry the soil sample overnight in an oven.
2. Crush the soil gently in a mortar and pestle.
3. Sieve the soil through a 16-mesh sieve to remove larger particles.
4. Weigh out 5g of soil.
5. Add distilled water, let sit for 5 minutes. Measure pH value.
6. Transfer to centrifuge bottles. Fill with distilled water. Centrifuge and decant.

Carbonate and Oxide Removal

1. Transfer samples to fleakers or beakers.
2. Add 50 mL glacial acetic acid to each sample.
3. Place samples in hot water bath (approx. 90º C) for one hour. Record any reaction.
4. Transfer samples into centrifuge tubes. Centrifuge and decant. Repeat twice.

Organic Removal

1. Wash samples into beakers or fleakers using 27% hydrogen peroxide.
2. Add approximately 50mL of hydrogen peroxide.
3. Place samples in hot water bath (approx. 90º C). Record any reaction.
4. Check after one hour by adding a little more hydrogen peroxide. If there is a reaction, add more hydrogen peroxide and let sit longer. Check every half hour. May need to centrifuge and decant, and add fresh hydrogen peroxide.
5. Samples are done when there is no reaction when fresh hydrogen peroxide is added. Generally organic removal took 2-2.5 hours for TAP samples.
6. Add distilled water, centrifuge and decant. Repeat twice.

Dispersion

1. Wash samples into large shaker bottles using 0.1% Na_2H_2 EDTA. Add enough of the solution to total about 200 mL.
2. Place bottles in shaker on low speed overnight.

Sieving

1. Place large funnel in ring stand, and small (250 micron) sieve inside funnel.
2. Pour sample through sieve into centrifuge bottle below. Repeat for each sample, washing equipment in between.
3. Centrifuge and decant. Wash into centrifuge tubes. Centrifuge and decant until supernatant is clear. This step needs to be repeated many times, for example, TAP samples required 8-10 times.

Heavy Liquid Flotation

1. Label two sets of test tubes, one for extract, one for residue.
2. Mix heavy liquid—for eight samples:
   Zinc iodide: 374.64 g
   Glacial acetic acid: 26.4 mL
   Distilled water: 106.4 mL
3. Place all components in medium beaker on hotplate, set to low heat. Stir. Let dissolve until all zinc iodide powder is in solution.
4. Check specific gravity of zinc iodide solution—it should be 2.3 g. Adjust if necessary by adding more distilled water or zinc iodide powder.
5. Fill empty 'extract' tubes with 30 mL distilled water.
6. Add 10 mL heavy liquid to each sample (in 'residue' tubes). Shake vigorously. Centrifuge at 3000 rpm for 5 minutes. Decant supernatant into respective tube labelled 'extract.'
7. Centrifuge extract tubes for 10 minutes at 3000 rpm. Decant supernatant into waste stream.
8. Repeat steps 4-7 twice.
9. Rinse residue and extract portions of each sample three times at 3000 rpm for 10 minutes.
10. Place samples in low heat oven overnight or for several days.

APPENDIX 1B:

Field Procedure for Sampling Artifacts for Phytolith and Starch Grain Analysis
30 July 2004 (Modified 05/2005)

Unwashed artifacts are preferred for sampling, because there is less chance of contamination and likely more residue adhering to the surface. The following is a field adaptation of the sampling procedure reported in Pearsall et al. 2004. Be sure to use standard laboratory protocols to avoid contamination, for example wear gloves when handling artifacts, change gloves for each new artifact, and use a new toothbrush for each artifact. Distilled water should be used for this procedure. If this is not possible, please be sure to take a sample of the water used and send it to the phytolith analyst. Photos should be taken of each artifact before and after sampling. A record or log should be kept of which artifacts were sampled, whether they were unwashed or previously washed, contextual information (site, locus, unit), any procedural notes, and corresponding photo numbers.

For unwashed artifacts:

1. Record contextual information in sampling log. Label three bags large enough to fit artifact inside with site, locus, and unit information, and mark Sediment 1, 2, or 3. Put new gloves on.
2. Place artifact inside bag labelled Sediment 1. Using a new, clean toothbrush scrub off dry sediment, keeping the artifact and sediment inside the bag. This is Sediment 1.
3. Put the artifact in bag labelled Sediment 2. Add some distilled water and using the same toothbrush scrub the artifact, keeping the artifact and sediment inside the bag as above. Most of the adhering sediment should be removed in this step. Remove the artifact from the bag. Seal the bag and put it aside.
4. Put the artifact in the bag labelled Sediment 3, or if it is small enough, place it inside a bottle. Be sure to rinse each bottle with distilled water before use. Add enough distilled water to cover the artifact. Fill sonicator with water (filtered water is ok for this, there is no need to use distilled water as it never touches the artifact or sample). Place bottle/bag with artifact in sonicator. Water levels in the artifact bag/bottle should be the same as the water level in the sonicator. Press the on button to start the sonicator. It automatically runs for 5 minutes, which is usually sufficient for unwashed artifacts. If a lot of material remains on the artifact, you may wish to run the sonicator for an additional 5 minutes. Note how much time the artifact is in the sonicator, 5 or 10 minutes.
5. Using distilled water, rinse the artifact into bag/bottle, and place on original bag or elsewhere to dry. If using a bag, cut corner and drain liquid into bottle labelled Sediment 3. Rinse remaining material into bottle using distilled water. Also rinse the Sediment 2 bag into bottle labelled Sediment 2.
6. Three components should result: Sediment 1, in a bag, Sediment 2, in a bottle, and Sediment 3, in a bottle. All wet sediments are placed in bottles to facilitate transport later on.

For washed artifacts:

1. Washed artifacts are not brushed, only sonicated. Follow steps 4 and 5 above, except sonicate for 10 minutes in all cases.
2. Please note that the artifact was washed previously.

Decanting (pouring off excess liquid after sediment has settled to bottom) is not recommended unless absolutely necessary. If there is excess water in bottles, leave in a secure place for the sediment to settle out of the water on to the bottom of the bottles. When water is clear (after several days), you may CAREFULLY decant excess water. Smoothly pour the water out of the bottle into an extra container without agitating the sediment at the bottom. Leave at least 3 centimeters of water remaining on top of the sediment however. Remember that phytoliths and starch grains are transparent, so you will not be able to see if you are pouring them off or not. Please note in the log whether you have decanted the bottles.

For exportation or shipping, please make sure each bottle is tightly sealed and clearly labelled. Use duct tape or equivalent to seal each bottle. Pack bottles upright carefully with padding.

APPENDIX 2: ARCHAEOLOGICAL DATA

A. Artifact Residues

B. Photographs of Selected Artifacts Sampled

C. Soil Sample Context Information

D. Soil Sample Data: Diagnostic Indicators

E. Soil Sample Data: Short Cells (Old System)

F. Soil Sample Data: Short Cell Sample Population (New System)

Appendix 2A: TAP Artifact Residues

							Phytolith Data									Starch Data			
							Zea mays Narrow elongate rondel	cf. *Z. mays* Narrow elongate rondel	*Z. mays* Ruffle top rondel	cf. *Z. mays* Ruffle top rondel	Arecaceae spinulose sphere	Cyperaceae	Cucurbitaceae/Asteraceae hair	*Scirpus* sp.	Nodular sphere	*Zea mays*	cf. *Zea mays*	Tuber	Unidentifiable
Phyto #	**Starch #**	**Site**	**Locus**	**Unit**	**Object**	**Sed.**													
2290	309	Chiripa Quispe	3114/15	N1058 E1124	Mano de Moler-Floor	1													
2291	310	Chiripa Quispe	3114/15	N1058 E1124	Mano de Moler-Floor	2	2	1		5									
2292	311	Chiripa Quispe	3114/15	N1058 E1124	Mano de Moler-Floor	3										1			
2293	312	Kala Uyni	5268	N894 E639	Whole Mandible	1										1			1
2294	313	Kala Uyni	5268	N894 E639	Whole Mandible	2		3		2				2					
2295	314	Kala Uyni	5268	N894 E639	Whole Mandible	3													1
2296	315	Sonaji	6090	N989 E994	Large hoe	1													
2297	316	Sonaji	6090	N989 E994	Large hoe	2		1				1							
2298	317	Sonaji	6090	N989 E994	Large hoe	3													
2299	318	Sonaji	6154/6	N1001 E1035	Ceramic trumpet fragment	1													
2300	319	Sonaji	6154/6	N1001 E1035	Ceramic trumpet fragment	2													1
2301	320	Sonaji	6154/6	N1001 E1035	Ceramic trumpet fragment	3													
2302	321	Kumi Kipa	6561/5	N906 E936	Mano	1													
2303	322	Kumi Kipa	6561/5	N906 E936	Mano	2		1											
2304	323	Kumi Kipa	6561/5	N906 E936	Mano	3					cf. 1								
2305	324	Kala Uyni	5282	N973 E933	Right Mandible	1													
2306	325	Kala Uyni	5282	N973 E933	Right Mandible	2	2	1							1				
2307	326	Kala Uyni	5282	N973 E933	Right Mandible	3													
2308	327	Chiripa Quispe	3132-A	N1057 E1127	Mano de Moler	1													
2309	328	Chiripa Quispe	3132-A	N1057 E1127	Mano de Moler	2	2	6							1				
2310	329	Chiripa Quispe	3132-A	N1057 E1127	Mano de Moler	3										2			
2311	330	Sonaji	6080	N989 E994	Scapula comb	3									1				
2312	331	Kumi Kipa	6617	N868 E922	Llama mandible scraper	3													
2313	332	Chiripa	1326 S	CD	Slate knife fragment	3													
2356	358	Chiripa Quispe	3109-A	N1058 E1124	Mano de Moler	2	3	5							1				
2357	359	Chiripa Quispe	3109-A	N1058 E1124	Mano de Moler	3											1		
2358	360	Chiripa Quispe	3109-B	N1058 E1124	Metate fragment	2	6	5											
2359	361	Chiripa Quispe	3109-B	N1058 E1124	Metate fragment	3	1	1											1
2360	362	Kumi Kipa	6782/5	N860 E921	Tiw. 1 ceramic vessel	2	1	3		3	1			1	1	1			

Appendix 2A: TAP Artifact Residues Continued

							Phytolith Data									Starch Data			
							Zea mays Narrow elongate rondel	cf. *Z. mays* Narrow elongate rondel	*Z.mays* Ruffle top rondel	cf. *Z. mays* Ruffle top rondel	Arecaceae spinulose sphere	Cyperaceae	Cucurbitaceae/Asteraceae hair	*Scirpus* sp.	Nodular sphere	*Zea mays*	cf. *Zea mays*	Tuber	Unidentifiable
Phyto #	**Starch #**	**Site**	**Locus**	**Unit**	**Object**	**Sed.**													
2361	363	Chiripa Quispe	3135	N1057 E1127	Crucible	2													
2362	364	Chiripa Quispe	3135	N1057 E1127	Crucible	3													1
2363	365	Chiripa	2165	CD	Ceramic trumpet fragment	3													
2364	366	Sonaji	6102/6	N1001 E1035	Trompo	2													
2365	367	Sonaji	6102/6	N1001 E1035	Trompo	3													
2366	368	Kumi Kipa	6523/5 In	N838 E983	Tiwanaku Incensario	2	2	4		2									
2367	369	Chiripa	3016	CD	Ceramic trumpet fragment	3													
2368	370	Chiripa Quispe	3110-B	N1058 E1124	Mano de Moler	2	1	2											
2369	371	Chiripa Quispe	3110-B	N1058 E1124	Mano de Moler	3		4				2	1						1
2370	372	Chiripa Quispe	3110-A	N1058 E1124	Mano de Moler	2	3	10											
2371	373	Chiripa Quispe	3110-A	N1058 E1124	Mano de Moler	3													
2382	377	Chiripa Quispe	3133	N1057 E1127	Crucible (5 pieces)	2													
2383	378	Chiripa Quispe	3133	N1057 E1127	Crucible (5 pieces)	3													1
2384	379	Chiripa Quispe	3125	N1060 E1128	Mano de Moler	2													
2385	380	Chiripa Quispe	3125	N1060 E1128	Mano de Moler	3													
2386	381	Chiripa Quispe	3114/24	N1058 E1124	Mano de Moler-Floor	2													
2387	382	Chiripa Quispe	3114/24	N1058 E1124	Mano de Moler-Floor	3													2
2388	383	Chiripa Quispe	3113	N1058 E1124	Mano de Moler	2													
2389	384	Chiripa Quispe	3113	N1058 E1124	Mano de Moler	3													1
2390	385	Kala Uyni	5316 R	N894 E639	Right Mandible	2													
2391	386	Kala Uyni	5316 R	N894 E639	Right Mandible	3													3
2392	387	Kumi Kipa	6673/5	N872 E925	Whole Mandible	2													
2393	388	Kumi Kipa	6673/5	N872 E925	Whole Mandible	3													
2394	389	Chiripa	565	CD	Slate knife fragment	3													1
2395	390	Sonaji	6048	N989 E994	Llama mandible scraper	3												1	

Please note: Additions to locus numbers (eg. 3110-A) are my notations if I sampled from more than one artifact in that locus.
Due to time constraints, only the starch portion of samples 2382-2395 were formally scanned.

APPENDIX 2B: PHOTOGRAPHS OF SELECTED ARTIFACTS SAMPLED

Examples of Productive Artifact Types

Figure 10.1: Tiwanaku 4/5 *Incensario* (KK, L.6523), Contained maize

Figure 10.2: Tiwanaku 1 pot (KK, L. 6782) Contained maize, palm, and possibly Marantaceae

Figure 10.3: Mano from Chiripa Quispe (L. 3114/5), Contained maize

Figure 10.4: Metate fragment from Chiripa Quispe (L. 3109-B), Contained maize

Figure 10.5: Human mandible from KU, (L.5268), Contained maize on teeth

Figure 10.6: Llama mandible scraper from Sonaje (L. 6048), Contained one tuber starch grain

Examples of Artifact Types that were NOT Productive

Figure 10.7: Large stone hoe from Sonaje (L. 6090/5), No diagnostic phytoliths or starch

Figure 10.8: Slate knife from Chiripa (L. 91-2), No diagnostic phytoliths or starch

Figure 10.9: Scapula comb from Sonaje (L. 6012) No diagnostic phytoliths or starch

Figure 10.10: Crucible from Chiripa Quispe (L. 3133), No diagnostic phytoliths or starch

APPENDIX 2C: SOIL SAMPLE CONTEXT INFORMATION (KALA UYNI)

Area	MU#	Locus	Unit	Context Description
AC				
	2249	5017	N968E921	Event A23; Pit cut into floor of court (Am)
	2193 2206	5018	N968E921	Event A24; Upper floor of lower sunken court (Am)
	2200	5020	N968E921	Event A12; Lower floor of lower court (Am)
	2247	5111	N962E928	Southern unit; Floor, well preserved, thick distinct floors with lots of carbon (And)
	2245	5112	N962E928	Southern unit; Floor, well preserved, thick distinct floors with lots of carbon (And)
	2244	5184	N980.4E928.18	Northern unit; A sloping floor, looked distinct from southern unit (And)
	2250	5233	N990E968	Event A108; Midden below rocks associated with court (Am)
	2201	5238	N979E957	Event A111; Midden (Am)
	2251	5294	N975E917	Eastern unit; floor, or perhaps fill between floors (And)
	2202	5325	N982E955	Event A138; Floor of upper court (Am)
	2203 2241	5343	N993E952.5	Event A116; Upper floor of upper court (Am)
	2204	5345	N993E952.5	Event A119; Lower floor of upper court (Am)
	2191 2205	5380	N975E917	Eastern unit; floor (And)
AQ				
	2192 2192a 2192b 2192c 2192d	5082	N857E539	Single, well preserved midden event (Ma)
	2246	5085	N857E539	Single, well preserved midden event (Ma)
	2252	5091	N857E539	Single, well preserved midden event (Ma)
KU				
	2253	5043	N890E653	NA
	2242	5154	N892E653	NA
	2195 2195a 2195b 2195c 2195d	5164	N890E651	NA
	2254	5168	N890E651	NA
	2194 2207	5170	N890E651	NA
	2243	5318	N894E639	NA
	2255	5357	N892E653	NA
	2248	5358	N890E651	NA
	2256	5363	N894E651	NA

APPENDIX 2D: SOIL SAMPLE DATA: DIAGNOSTIC INDICATORS (KALA UYNI)

			Maize indicators					Hair Fragments					Hair bases				Cyperaceae							Environmental					
Site	TAP Locus	MU No.	**Narrow elongate rondel**	cf. Narrow elongate rondel	**Ruffle top rondel**	Regular IRP	Irregular IRP	Double outline	Segmented	Armed	Other	Total Hair Frag	cf. *Cordia lutea*	cf. Boraginaceae	Hair Bases	Conical bodies	Seed epidermal -- *Carex*	Seed epidermal -- *Scirpus*	Leaf epidermal	Epidermal Quadrilaterals	Epidermal Non-Quad	Nodular sphere	Spheres	Trichomes	Bulliform cells	Cystoliths	Diatoms	Sponge Spicules	Rows Scanned
AQ	5082	2192c	**0**	3	**0**	0	0	**7+**	1	0	**95**	**103**	**1**	0	**5**	1	0	0	**1**	1	2	0	0	26	0	7	39	9	E
KU	5164	2195c	**1**	1	**0**	0	0	0	0	0	11	11	0	0	0	0	0	0	0	0	0	0	1	9	0	5	12	5	E
AC	5020	2200	**1**	2	**0**	0	0	0	0	1	5	5	0	0	1	1	0	0	0	0	3	0	1	16	0	0	27	1	E
AC	5238	2201	**0**	4	**0**	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	2	VA	0	0	53	0	E
AC	5325	2202	**4**	4	**0**	0	0	1	0	0	1	2	0	0	4	1	0	0	3	0	3	0	1	0	0	**13**	**119**	0	E
AC	5345	2204	**0**	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	16	E
AC	5380	2205	**2**	5	**0**	0	0	1	0	0	0	1	0	0	3	1	0	0	2	1	**4**	0	1	13	0	7	32	21	E
AC	5018	2206	**1**	2	**0**	0	0	7	0	1	0	8	0	0	7	0	0	0	1	1	2	0	1	51	0	7	28	28	E
KU	5170	2207	**0**	3	**0**	0	0	0	0	0	0	0	0	0	2	2	**1**	0	0	0	1	0	2	41	0	6	20	46	E
AC	5343	2241	**0**	0	**0**	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0	0	0	5	0	4	6	21	E
KU	5154	2242*	**4**	5	**0**	0	0	–	–	–	–	–	0	0	–	–	0	0	–	–	–	**1**	–	–	–	–	–	–	–
KU	5318	2243	**5**	6	**0**	0	0	2	**3**	0	24	29	0	0	0	0	0	1	0	**2**	0	0	2	12	0	0	37	**56**	A
AC	5184	2244	**2**	5	**0**	0	0	0	0	0	20	20	0	0	2	0	0	0	0	1	2	0	2	44	0	11	21	17	A
AC	5112	2245	**1**	3	**0**	0	0	0	0	0	25	25	0	0	2	1	0	0	0	0	3	0	6	70	0	11	16	22	A
AQ	5085	2246	**3**	4	**1**	0	0	0	0	0	43	43	0	**1**	2	**3**	0	**2**	0	0	0	0	**9**	**144**	**2**	5	42	29	E
AC	5111	2247*	**5**	6	**0**	0	0	–	–	–	–	–	0	0	–	–	0	0	–	–	–	0	–	–	–	–	–	–	–
KU	5358	2248	**2**	4	**0**	0	0	0	0	1	6	7	0	0	1	0	0	1	0	**2**	3	0	3	20	1	0	29	53	A
AC	5017	2249	**0**	2	**0**	0	**1**	0	0	0	16	16	0	0	0	0	0	0	0	0	0	0	0	60	0	2	7	7	A
AC	5233	2250	**1**	1	**0**	**1**	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	25	0	1	9	26	A
AC	5294	2251	**0**	1	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	18	14	A
Total			**32**	61	**1**	1	1	11	5	3	251	277	1	1	30	12	1	4	7	8	23	1	32	558	3	79	517	371	

KEY: E= Every row
A= Alternate rows
VA=Very abundant

* These samples were only scanned for economic (e.g. maize) and hallucinogen diagnostics; full counts of all soil/environmental indicators were not made.

APPENDIX 2E: SOIL SAMPLES: SHORT CELLS (Old System) (KALA UYNI)

			Simple			Lobed		Rondel					Saddle		
Area	TAP Locus	MU No.	Panicoid	Festucoid	Chloridoid	Compressed bilobate	Total Other Lobed	Elongate**	Narrow, many spikes	Thin square	Pointed cone	Total Other Rondel	Total Other Saddle	Total Count	Number of Rows
AQ	5082	2192c*	32	55	31	2	4	22	0	4	0	79	1	202	3
KU	5164	2195c*	35	62	22	1	5	22	0	4	0	78	0	201	5
AC	5020	2200	53	51	8	1	10	11	6	6	0	81	1	200	4
AC	5238	2201	24	88	23	0	2	13	0	2	1	64	1	202	2.5
AC	5325	2202	23	82	34	1	7	12	0	4	0	61	0	200	1
AC	5345	2204	8	89	12	2	4	48	0	4	13	91	0	201	9
AC	5380	2205	21	103	9	1	3	20	0	3	0	67	0	203	2.25
AC	5018	2206	22	65	12	1	1	21	0	20	0	101	0	201	1.5
KU	5170	2207	13	78	10	3	4	30	0	0	0	94	1	200	3
AC	5343	2241	28	82	21	1	3	22	0	4	3	67	1	202	2
KU	5318	2243	45	65	17	0	0	9	0	11	0	75	0	202	1.5
AC	5184	2244	38	53	15	0	0	12	0	0	0	95	0	201	3.25
AC	5112	2245	23	72	26	0	2	10	0	0	0	76	0	199	1.25
AQ	5085	2246	22	78	13	1	1	23	0	6	2	86	0	200	1
KU	5358	2248	30	80	17	0	0	17	0	0	0	80	0	208	3.5
AC	5017	2249	20	137	4	0	2	3	1	10	2	40	0	203	3
AC	5233	2250	12	125	7	0	0	15	0	0	0	62	0	206	3
AC	5294	2251	18	114	9	0	0	6	0	2	0	59	0	200	3.5
Total			467	1479	290	14	48	316	7	80	21	1356	5		

* These samples prepared with half the normal amount of extract, as they were too dense to scan.

** This category is not the same as the Narrow Elongate rondel diagnostic of maize, but it probably includes some diagnostics.

NB: These counts were done using the normal MU grass short cell typology (in 2003/4), not the Andean typology created as part of this study (in 2005/6). A sub-sample was rrecounted using the new typology. Note the large Total Other Rondel category. Prior to the construction of a highland Andean grass typology, there was not an appropriate way to categorize this variation.

All samples, however, were re-scanned for the narrow elongate rondel (Appendix 2C).

APPENDIX 2F: NEW SHORT CELL COUNT DATA: Kala Uyni Sample Population (04/2006)

			MAIZE			SIMPLE			CONICAL						RONDEL		SQUARE		LOBED					SADDLE		OTHER			
Area	TAP Locus	MU No.	Narrow elongate rondel	cf. Narrow elongate ronde	Ruffle top rondel	Panicoid	Festucoid	Chloridoid	2A	2B	2C	2D	2E	2F	3A	3B	4A	4B	5A	5B	5C	5D	5E	6A	6B	7A	7B	7C	TOTAL COUNT
AQ	5082	2192c	0	3	0	20	41	5	7	0	3	0	3	0	8	10	0	0	0	0	0	0	0	0	0	0	0	2	102
AC	5238	2201	0	4	0	6	22	0	9	2	2	6	20	6	16	7	0	2	0	0	0	0	0	0	0	0	0	0	102
AC	5343	2241	0	0	0	9	43	6	5	1	0	5	5	2	14	6	1	0	1	0	2	0	0	0	0	0	0	0	100
KU	5154	2242	4	5	0	7	52	4	8	1	0	1	9	0	9	6	0	0	0	0	0	0	0	0	0	0	0	0	106
KU	5318	2243	5	6	0	22	32	8	2	2	1	3	1	2	7	3	0	0	0	0	3	0	0	0	0	0	0	3	100
AC	5184	2244	2	5	0	11	43	2	7	2	0	3	2	1	12	14	0	0	1	0	0	0	0	0	0	0	0	0	105
AQ	5085	2246	3	4	1	9	40	3	8	0	0	3	4	3	21	4	0	1	1	0	0	0	0	0	0	0	0	0	105

NB: Grass Data presented here were obtained using the highland Andean grass typology developed in this study.
Only a subsample of the soil samples were re-counted using the new Andean grass typology due to time limitations.

APPENDIX 3: COMPARATIVE PLANT DATA

A. Phytolith Production in Hallucinogens

B. Grass Taxa Sampled

C. Andean Grass Typology

D. Summary Grass Data

E. Full Grass Data

APPENDIX 3A: Phytolith Production in Hallucinogens

Common Name	Family	Scientific Name	MU #	Plant part	Phytoliths	Calcium Oxalate
Vilca	Fabaceae	*Anadenanthera colubrina*	NA	seed	No diagnostic phytoliths	NA
			NA	pod	Polyhedral phytolith with central depression, heavily silicified with 'stripes'--DIAGNOSTIC	NA
					Non-quadrilateral epidermal cells--not diagnostic	
Ayahuasca	Malpighiaceae	*Banisteriopsis sp.*	3027	bark	low silica concentration; no diagnostic phytoliths	Druses with pointed projections, not diagnostic
		Banisteriopsis caapi	3029	bark	low silica concentration; no diagnostic phytoliths	Druses with pointed projections, not diagnostic
			3028	leaf	Hair cell base--POSSIBLY DIAGNOSTIC Large epidermal non-quadrilateral--POSSIBLY DIAGNOSTIC Triangular, tent shaped body--POSSIBLY DIAGNOSTIC Hat shaped body--not diagnostic Stomata--not diagnostic	Druses with pointed projections, not diagnostic
Floripondio	Solanaceae	*Brugmansia aurea*	3014	stem/bark	low silica concentration; no diagnostic phytoliths	
			3013	flower	Tissue with rod inclusions--not diagnostic Small, light brown nondescript spheres--not diagnostic Tissue with faint surface decorations--not diagnostic	Tissue with rod inclusions--not diagnostic
			3012	leaf	Multicellular hairs--potentially useful Non-quadrilateral epidermal cells--not diagnostic Smooth tubular body, pinched ends--not diagnostic	Spheres with pointed projections--not diagnostic
			3011	seed	low silica concentration; no diagnostic phytoliths	Single raphides--not diagnostic
Jimsonweed	Solanaceae	*Datura inoxia*	3025	leaf	Multicellular hairs--potentially useful Large scalloped hemispheres--not diagnostic Hair cell bases/stomata--POSSIBLY DIAGNOSTIC	Flower druses--not diagnostic
			3015	seed	Roughly quadrilateral epidermal cells with long, rounded projections--not diagnostic	None diagnostic
Coca	Erythroxylaceae	*Erythroxylum coca*	2749	leaf	No diagnostic phytoliths	Tissue with rod inclusions--not diagnostic Elongated polygon with calcium oxalate core--not diagnostic
			2784	seed	No diagnostic phytoliths	None diagnostic
Mate	Aquifoliaceae	*Ilex retusa*	3018	leaf	Star to cloud shaped silica bodies--not diagnostic	Variable spheres--not diagnostic
Tobacco	Solanaceae	*Nicotiana rustica*	3019	leaf	Large multicellular hair--potentially useful	None diagnostic
			3016	roots	Double outline, keeled hemisphere--not diagnostic	None diagnostic
		Nicotiana tobaccum	3026	leaf	Big, smooth spheres--not diagnostic	None diagnostic
	Cactaceae	*Opuntia cylindrica*	3021	stem/flesh	Roughly cylindrical, small unknown body--not diagnostic low silica concentration; no diagnostic phytoliths	Large druses with triangular projections--not diagnostic Probably not diagnostic
Chacruna	Rubiaceae	*Psychotria viridis*	3023	fruit	Small smooth spheres--not diagnostic Diamond shaped, double outline body--not diagnostic	Raphide bundles--not diagnostic Small spheres/druses--not diagnostic
			3024	leaf	Silicified, scalloped tissue--potentially useful Stomata--not diagnostic Roughly quadrilateral epidermal cell--not diagnostic	Raphide bundles--not diagnostic
San Pedro cactus	Cactaceae	*Trichocereus cuzcoensis*	3022	stem/flesh	Epidermal phytoliths, very rare, not diagnostic	Medium sized spheres--not diagnostic
	Myristaceae	*Virola nobilis*	3005	bark	Low silica concentration; no diagnostic phytoliths	None diagnostic
		Virola peruviana	3006	bark	Low silica concentration; no diagnostic phytoliths	None diagnostic
			3004	inner bark	Low silica concentration; no diagnostic phytoliths	None diagnostic
			3008	leaf	Rectangular, double outline bodies--not diagnostic	Spheres with pointed projections--not diagnostic
			3007	pod	Low silica concentration; no diagnostic phytoliths	None diagnostic
			3030	seed	Lightly silicified cells, not diagnostic	Blocks--not diagnostic

Notes: The most used or appropriate species for each genus were not always available at MOBOT; another species from South America was tested, if available.
Phytolith types are evaluated more fully in the written descriptions.
Here they are designated (in order of their diagnostic potential) as DIAGNOSTIC, POSSIBLY DIAGNOSTIC, potentially useful, and not diagnostic.
Abundance information not reported.

APPENDIX 3B: GRASS TAXA SAMPLED

MU No.	Scientific Name	Country	Part	MU No.	Scientific Name	Country	Part
	FESTUCOID						
2980	*Aciachne acicularis*	Bo, Ec	infl	2820	*Elymus erianthus*	Ec	infl
2816	"		leaf	2946	"		leaf
2984	*Agrostis breviculmis*	Bo, Ec	infl	2825	*Festuca dolichophylla*	Bo, Ec	infl
2972	"		leaf	2951	"		leaf
2990	*Agrostis tolucensis*	Bo, Ec	infl	2823	*Festuca glyceriantha*	Bo, Ec	infl
2817	"		leaf	2949	"		leaf
2991	*Alopecurus aequalis*	Bo, Ec	infl	2824	*Festuca subulifolia*	Bo, Ec	infl
2970	"		leaf	2950	"		leaf
2983	*Anthochloa lepidula*	Bo	infl	2919	*Hierochloe redolens*	Bo (v. rare), Ec	infl
2813	"		leaf	2953	"		leaf
3064	*Aphanelytrum procumbens*	Bo (rare), Ec	infl	2826	*Koeleria kurtzii*	Bo (rare)	infl
2969	"		leaf	2952	"		leaf
2992	*Brachypodium mexicanum*	Ec	infl	2974	*Melica adhaerens*	Ec	infl
2968	"		leaf	2954	"		leaf
2993	*Briza minor*	Ec	infl	2976	*Melica scabra*	Ec	infl
2945	"		leaf	2955	"		leaf
2910	*Bromus lanatus*	Bo, Ec	infl	2830	*Nassella brachyphylla*	Bo, Ec	infl
2943	"		leaf	2956	"		leaf
2911	*Bromus segetum*	Bo, Ec	infl	2982	*Nassella pubiflora*	Bo, Ec	infl
3065	"		leaf	2957	"		leaf
	Calamagrostis intermedia	Ec	infl	2975	*Ortachne erectifolia*	Ec	infl
2805	"		leaf	2959	"		leaf
	Calamagrostis rigida	Ec	infl	2835	*Piptochaetium stipoides*	Bo, Ec	infl
2804	"		leaf	2833	"		leaf
2914	*Catabrosa werdermanii*	Bo (v. rare)	infl	2836	*Poa nevadensis*	Bo, Ec	infl
2986	"		leaf	2847	"		leaf
2988	*Deschampsia caespitosa*	Ec	infl	2981	*Puccineillia frigida*	Bo (rare), Ec	infl
2794	"		leaf	3067	"		leaf
2916	*Dielsiochloa floribunda*	Bo	infl	2839	*Stipa ichu*	Bo, Ec	infl
2796	"		leaf	2844	"		leaf

APPENDIX 3B: GRASS TAXA SAMPLED CONTINUED

MU No.	Scientific Name	Country	Part
	FESTUCOID CONTINUED		
	Dissanthelium minimum	Bo	infl
2792	"		leaf
2917	*Dissanthelium peruvianum*	Bo	infl
3066	"		leaf
2821	*Elymus cordilleramus*	Ec	infl
2947	"		leaf
	CHLORIDOID		
2985	*Aegopogon cenchroides*	Ec	infl
2973	"		leaf
2915	*Chondrosum simplex*	Bo	infl
2942	"		leaf
2935	*Eragrostis ciliaris*		infl
2961	"		leaf
2934	*Eragrostis mexicana*		infl
2960	"		leaf
2832	*Microchloa indica*	Bo	infl
2958	"		leaf
2909	*Munroa mendocina*	Bo (rare)	infl
2944	"		leaf
2939	*Sporobolus pyramidatus*	Ec	infl
2965	"		leaf
2938	*Sporobolus virginicus*	Ec	infl
2964	"		leaf
2840	*Trichiochloa stipoides*	Ec	infl
2843	"		leaf
	ARUNDINOID		
2912	*Cortaderia bifida*	Bo, Ec	infl
2798	"		leaf
2918	*Cortaderia hapalotricha*	Bo, Ec	infl
2797	"		leaf

MU No.	Scientific Name	Country	Part
2838	*Stipa obtusa*	Bo, Ec	infl
2845	"		leaf
2841	*Trisetum spicatum*	Bo, Ec	infl
2842	"		leaf
2920	*Vulpia myuros*	Ec	infl
3068	"		leaf
	PANICOID		
2987	*Andropogon bicornis*	Ec	infl
521	"		leaf
	Andropogon selloanus	Ec	infl
2801	"		leaf
2979	*Andropogon ternatus*	Ec	infl
2802	"		leaf
2822	*Erioneuron avenaceum*	Bo (v. rare)	infl
2948	"		leaf
2936	*Paspalum racemosum*		infl
2962	"		leaf
	HIGHLAND MAIZE		
3069	*Zea mays* 'canguil'	Otavalo, Ec	husk
3070	"		infl
3071	*Zea mays*	La Chimba	husk
3072	"		infl
3073	*Zea mays* sweet corn	Huancayo, P	infl
3075	*Zea mays* 'confinite puneno'	Cuzco, P	infl
3076	*Zea mays* 'Huayleno'	Cuzco, P	infl
3077	*Zea mays* 'Piscorrunto hybrid?	Huancayo, P	infl
3078	*Zea mays* 'Purple Chicha'	Peru	infl

KEY: Bo=Bolivia
Ec=Ecuador
P=Peru

NOTES: All wild grass genera are typical of habitats above 3000 m.a.s.l. Species are South American, unless there were none available.
If no MU number is provided, the sample was problematic or not available, and is not analyzed.

APPENDIX 3C
Andean Grass Typology
Andean Bolivia and Ecuador ONLY

KEY: L=leaf, I=inflorescence, VR=very rare, R=Rare, abundance noted only where R or VR, otherwise is Moderate to Very Abundant

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Category 1: Simple (not classified further): top and base are mirror-images

Lobed base

Rondel/rectangular/sinuous base

Saddle base

Category 2: Conical (circular base)[1]: top is smaller then base, general 3-D shape is conical

A: Conical, Flat Plateau Top: Base is generally circular to slightly irregular; sides are generally slanted to flaring at base, may be shouldered (*Agrostis breviculmis* L, *Agrostis tolucensis* I,L, *Brachypodium mexicanum* L, *Bromus lanatus* L, *Elymus cordilleramus* I, *Festuca glyceriantha* L, *Festuca subulifolia* L, *Koeleria kurtzii* L, *Ortachne erectifolia* I)

a. Very small cone, top is flat to bifurcate, sides almost straight (*Sporobolus virginicus* L,I)→DIAGNOSTIC
b. Tall, large, heavily silicified cone with nearly straight sides and plateau top (*Elymus erianthus* L)→DIAGNOSTIC

B. Conical, Rounded, Decorated Top: Base is circular, sides often flare sharply at base, top is covered in small rounded projections or bumps (*Brachypodium mexicanum* L—VR, *Calamagrostis intermedia* L, *Calamagrostis rigida* L, *Festuca dolichophylla* I, *Hierochloe redolens* L—VR, *Poa nevadensis* L)

a. Tall, cylindrical body with bumpy top (*Festuca glyceriantha* L, *F. subulifolia* L, *Piptochaetium stipoides* L but VR and flares more-CUT)

C: Conical, irregular top: top is ephemeral to almost decorated or spiked, but very thin and hard to distinguish, bodies generally thin and tall (*Aphanelytrum procumbens* I—VR, *Elymus cordilleramus* I, *Nassella brachyphylla* I, *Piptochaetium stipoides* L, I, *Zea mays* sweet corn I—R)

a. Extremely thin, small top ("pencil-like") with irregular, ephemeral top that is almost spiked, sides flare sharply outwards half-way down, base is circular to rondel (*Piptochaetium stipoides* L)→DIAGNOSTIC
b. Three low spikes on top, sides slant slightly (*Erionueron avenaceum* L—VR)
c. Bifurcate top, with circular base: (*Dissanthelium minimum* L, *Festuca subulifolia* I, *Ortachne erectifolia* I)

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[1] Please note: Most analysts do not separate conical from rondel forms. Conical is generally subsumed as a subset of rondel base. However, for my purposes there is a notable difference between the two, in fact, conical forms are the most common complex types in festucoid grasses. Conical forms can also be separated easily from elongated rondels.

D: Conical, pointed top: top comes to point in side view and from top, or may be more open and flat at top (*Aciachne acicularis* L, I, *Agrostis breviculmis* L, I, *Aphanelytrum procumbens* L, *Brachypodium mexicanum* I, *Briza minor* I, *Calamagrostis intermedia* L—VR, *Calamagrostis rigida* L, *Dielsiochloa floribunda* L, *Elymus cordilleramus* I—VR, *Elymus erianthus* I—VR, *Festuca dolichophylla* L, *Hierochloe redolens* L, *Melica adhaerens* I, *Melica scabra* L, *Nassella brachyphylla* I—R, *Nassella pubiflora* I, *Ortachne erectifolia* I, *Stipa obtusa* I, *Trisetum spicatum* I)

a. Flattened, elongated rondel base with pointed top: *Calamagrostis rigida* L→DIAGNOSTIC

E: Conical, thin ridge top, concave, flared sides: (*Agrostis breviculmis* L, *Agrostis tolucensis* L,I, *Brachypodium mexicanum* L, *Bromus lanatus* I, *Calamagrostis rigida* L, *Cortaderia bifida* I (different slightly), *Deschampsia caespitosa* L, *Diesiochloa floribunda* L, *Dissanthelium peruvianum* I, *Festuca dolichophylla I*, *Festuca glyceriantha* L, *Melica scabra* L—R, *Stipa obtusa* L, *Vulpia myuros* L)

a. Long thin upper half, flares dramatically at base, ruffled circular base: *Calamagrostis intermedia* L—R, *Nassella brachyphylla* I—R)
b. With decorated base: (*Alopecurus aequalis* I, *Briza minor* I, *Vulpia myuros* I)
c. Two-spiked top: *Aciachne acicularis* L—R →DIAGNOSTIC

F: Domed, thin top: (*Agrostis breviculmis* I—VR, *Brachypodium mexicanum* I, *Bromus segetum* I, *Deschampsia caespitosa* L—VR, *Elymus cordilleramus* I, *Elymus erianthus* L, *Festuca dolichophylla* I, *Festuca subulifolia* I, *Stipa obtusa* L—VR, *Vulpia myuros* L—R)

Category 3: Rondel base: elongated

A: Classic to irregular rondel base, top comes to keel ('ridge'), usually elongate: (*Aciachne acicularis* L, *Agrostis breviculmis* L, *Agrostis tolucensis* I, *Brachypodium mexicanum* L—VR, *Bromus segetum* I, *Calamagrostis rigida* L, *Chondrosum simplex* L—VR, *Cortaderia hapalotricha* I, *Deschampsia caespitosa* I, *Diesiochloa floribunda* L, *Dissanthelium minimum* L—VR, *Hierochloe redolens* L, *Melica adhaerens* I—VR, *Melica scabra* L—VR, *Nassella brachyphylla* L,I, *Stipa obtusa* I, *Vulpia myuros* L, *Zea mays* I) (Originally 3Aa)

a. Slanted sides, triangular: (*Alopecurus aequalis* L, *Poa nevadensis* L, *Stipa obtusa* L—VR, *Zea mays* La Chimba H) (originally 3Ab)
b. Sides flare only at base: (*Aphanelytrum procumbens* L, *Bromus lanatus* I, *Elymus erianthus* I) (Originally 3Ac)
c. Straight sides, three thin spikes on top: *Elymus erianthus* I (Originally 3Ad)→DIAGNOSTIC
d. Slanted sides, triangular, three thin spikes at top: *Calamagrostis rigida* L—VR (Originally 3Ae)→DIAGNOSTIC
e. Sides concave, flare sharply at base and top, three spiked: *Brachypodium mexicanum* L (Originally 3Af)→DIAGNOSTIC
f. Sides flare at base, concave, two spiked top, more square from side view: *Agrostis tolucensis* I—VR (Originally 3Ag)→DIAGNOSTIC
g. Distinct kidney-bean shaped base, ridge top is semi-circular and meets edge of base from top view, top is flat or two spiked: *Festuca dolichophylla* I, *Festuca subulifolia* I → Festuca Inflorescence Type (Originally 3Ah)→DIAGNOSTIC
h. Ephemeral to spiked top, very thin, curved, convex or straight sides, rondel base [could be confused with wavy top, but top does not wave, it is much more ephemeral and irregular]: *Agrostis breviculmis* L, *Alopecurus aequalis* L, *Cortaderia bifida* I, *Elymus cordilleramus* I, *Elymus erianthus* I,L, *Festuca glyceriantha* L, *Koeleria*

kurtzii L, *Stipa obtusa* I, *Piptochaetium stipoides* I, *Poa nevadensis* I, L—VR, *Zea mays* H,I (Originally 3Ai)

i. Sinuous rondel to rectangular base, top is ephemeral to spiked, sides concave: *Dissanthelium minimum* L (Originally 3Aj)→DIAGNOSTIC
j. Elongate, thin, sinuous base, concave sides, flat ridge top: *Stipa obtusa* L, I (Originally 3Ak)→DIAGNOSTIC
k. Elongate, thin, sinuous base, straight sides, pointed edges on top: *Calamagrostis rigida* L, *Zea mays* La Chimba H—R (Originally 3Al)
l. Wavy top rondel: sides are straight but may curve outwards at base, top does not form spikes but 'waves', i.e. is not straight, base is classic rondel to irregular, very similar to 3Ah: (*Aegopogon cenchroides* I, *Bromus segetum* I—VR, *Festuca glyceriantha* I, *Festuca subulifolia* I,L, *Poa nevadensis* L—VR, *Stipa ichu* L—VA, *Zea mays* I) (Combined 3Am and 3An)

B: Flat, 'plateau' top, sides distinctly concave, top is slightly smaller than bottom, both top and bottom are oval or elongated rondel, may be somewhat irregular, top is flat not waved or peaked (Originally 3Bg)→MAIZE DIAGNOSTIC

a. Elongate, sides flare out slightly, top has central point from side view: *Festuca subulifolia* L—R , *Zea mays* canguil H
b. Base is irregular and ephemeral, top not parallel to bottom, but slanted, flat circle: *Bromus segetum* I, *Trisetum spicatum* L
c. Ruffle Top Rondel Confuser: Base is circular to rondel, top is nearly the same size and 'roughly' silicified to ephemeral, can be confused with ruffle top, but much more irregular (i.e. its ephemeral, but not indented/ruffled top): (*Andropogon bicornis* I, *Catabrosa werdermanii* L, *Cortaderia bifida* L—VR, *Elymus erianthus* I, *Festuca subulifolia* L, *Piptochaetium stipoides* I—VR, *Poa nevadensis* L—R, *Trisetum spicatum* L, *Zea mays* La Chimba H *Zea mays* I,H) (3Bf combined into this category)
d. Three or more long, rounded spikes, base irregular rondel: *Elymus erianthus* I
e. Ruffle top rondel, very similar to 3Bc, but top is distinctly ruffled/indented, not just ephemeral but forms a distinct design, sides are concave to straight: *Zea mays* I→MAIZE DIAGNOSTIC
f. Narrow Elongate Rondel: narrow, plateau top rondel with indented sides, top and bottom faces are heavily silicified→ MAIZE DIAGNOSTIC

Category 4: Square/rectangular base

A: Rectangular base, slanted sides, ridge top: *Poa nevadensis* L→DIAGNOSTIC

B: Plateau top (looks like smaller rectangle/oblong inside bigger rectangle from top), sides flared to straight: (*Aphanelytrym procumbens* L, I—VR, *Calamagrostis intermedia* L—VR, *Catabrosa werdermanii* I, *Chondrosum simplex* I, *Melica adhaerens* L, *Zea mays* La Chimba I) (Originally 4Ba)

a. Sides concave, flare at top, elongate: (*Calamagrostis rigida* L—R, *Festuca dolichophylla* L—R, *Festuca glyceriantha* L—VR, *Microchloa indica* L) (Originally 4Bb)
b. Base square, top ephemeral to spiked, sides straight to slanted: (*Piptochaetium stipoides* L, *Stipa obtusa* L) (Originally 4Bc)

Category 5: Lobed base

A: Small, squat, unpronounced bilobate base, top is ridged to plateau: *Trichiochloa stipoides* L, *Zea mays* La Chimba H

B: Cross base: irregularly ridge or spiked top, elongate: *Andropogon ternatus* L (Originally 5Ba and 5Bb→collapsed)→DIAGNOSTIC

C: Two-spiked top, elongate, bilobate to nearly sinuous base, concave to slanted sides: (*Aciachne acicularis* L, *Andropogon ternatus* I—VR, *Erionueron avenaceum* L, *Ortachne erectifolia* I,L, *Stipa obtusa* L, *Zea mays* I)

a. Two-spiked top, but very tall and straight sided, with squat bilobate base: *Aegopogon cenchroides* I→DIAGNOSTIC

D: Four-spiked top, squat bilobate base (*Andropogon ternatus* L—R, *Stipa ichu* L)(Originally 5Da)

a. Spikes are long and rounded, not on corners: *Andropogon ternatus* I (Originally 5Db)→DIAGNOSTIC

E: Ephemeral top, Bilobate base with very thin shank, small, irregular plateau top, sides flare at base: *Cortaderia hapalotricha* L (Originally 5Ea)→DIAGNOSTIC

F: Three or four lobed base, distinct square plateau top, but top is ephemeral from side view: *Aegopogon cenchroides* I (Originally 5Eb)→DIAGNOSTIC

Category 6: Saddle base

A: Extremely squat saddle base (twice as wide as long), ridge top, curved to wavy in side view: *Erioneuron avenaceum* L—R →DIAGNOSTIC

B: Small saddle based, ridge top, sides slant outwards at base: *Eragrostis ciliaris* I,L→DIAGNOSTIC

Category 7: Other

A: "U-shaped" base, sides straight to slightly curved, flat plateau top: *Koeleria kurtzii* L—R→DIAGNOSTIC

B: Base is distinct; three lobed to two indentations per side from top view, top is plateau (see card): *Festuca dolichophylla* L→DIAGNOSTIC

C: Short, square cross: *Trisetum spicatum* I—VR→DIAGNOSTIC

APPENDIX 3D: ANDEAN GRASS COUNT DATA SUMMARY

		Cat. 1			Cat. 2																Cat. 3									
		SIMPLE			CONICAL																RONDEL									
	n	Panicoid	Festucoid	Chloridoid	2A: Plateau	2Aa	2Ab	2B: Rounded, Decorated	2Ba	2C: Irregular top	2Ca	2Cb	2Cc	2D: Pointed top	2Da	2E: Ridge top	2Ea	2Eb	2Ec	2F: Dome	3A: Ridge top	3Aa	3Ab	3Ac	3Ad	3Ae	3Af	3Ag	3Ah	3Ai
FESTUCOID	68	58	1235	5	82	0	11	69	6	59	2	0	20	391	15	223	4	130	2	160	145	46	21	6	1	3	1	27	109	3
CHLORIDOID	16	79	273	276	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
PANICOID	9	245	166	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARUNDINOID	4	93	18	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	29	0	0	0	0	0	0	0	13	0
ALL WILD GRASSES	97	475	1692	291	82	100	11	69	6	59	2	1	20	391	15	253	4	130	2	160	175	46	21	6	1	3	1	27	122	3
MAIZE	9	67	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	86	5	0	0	0	0	0	0	10	0
ALL GRASSES	106	542	1696	291	82	100	11	69	6	61	2	1	20	391	15	253	4	130	2	160	261	51	21	6	1	3	1	27	132	3

		Cat. 3, Continued										Cat. 4				Cat. 5								Cat. 6		Cat. 7			
		RONDEL										SQUARE				LOBED								SADDLE		OTHER			
	n	3Aj	3Ak	3Al	3B: Plateau top	3Ba	3Bb	3Bc	3Bd	3Be	3Bf	4A: Ridge top	4B: Plateau top	4Ba	4Bb	5A: Ridged top bilobate	5B: Plateau top cross	5C: Two spike bilobate	5Ca	5D: Four spiked bilobate	5Da	5E: Ephemeral top	5F:Three or four lobed base	6A: Extremely squat base	6B: Small saddle base	7A: U-Shaped base	7B: Three lobe base	7C: Short, square cross	**TOTAL COUNT**
FESTUCOID	68	36	4	114	0	2	38	30	31	0	0	3	10	5	22	0	0	45	0	15	0	0	0	0	0	2	5	1	**3196**
CHLORIDOID	16	0	0	5	0	0	0	0	0	0	0	0	10	13	0	6	0	0	8	0	0	0	23	0	9	0	0	0	**803**
PANICOID	9	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	3	5	0	2	12	0	0	2	0	0	0	0	**451**
ARUNDINOID	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	**204**
ALL WILD GRASSES	97	36	4	119	0	2	38	36	31	0	0	3	20	18	22	6	3	50	8	17	12	20	23	2	9	2	5	1	**4649**
MAIZE	9	0	3	57	0	3	0	83	0	21	93	0	3	0	0	1	0	17	0	0	0	0	0	0	0	0	0	0	**455**
ALL GRASSES	106	36	7	176	0	5	38	119	31	21	93	3	23	18	22	7	3	67	8	17	12	20	23	2	9	2	5	1	**5104**

APPENDIX 3E: ANDEAN GRASS COUNT DATA

			Cat. 1			Cat. 2																Cat. 3								
FESTUCOID			SIMPLE			CONICAL																RONDEL								
MU#.	Taxa	Part	Lobed	Rondel	Saddle	2A	2Aa	2Ab	2B	2Ba	2C	2Ca	2Cb	2Cc	2D	2Da	2E	2Ea	2Eb	2Ec	2F	3A	3Aa	3Ab	3Ac	3Ad	3Ae	3Af	3Ag	3Ah
2980	*FAcac*	infl	0	22	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2816	*FAcac*	leaf	0	6	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	2	0	9	0	0	0	0	0	0	0	0
2984	*FAgbr*	infl	0	4	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2972	*FAgbr*	leaf	0	6	0	3	0	0	0	0	0	0	0	0	22	0	4	0	0	0	0	2	0	0	0	0	0	0	0	15
2990	*FAgto*	infl	0	0	0	13	0	0	0	0	0	0	0	0	0	0	34	0	0	0	0	2	0	0	0	0	0	1	0	0
2817	*FAgto*	leaf	0	13	0	5	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
2991	*FAlae*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0
2970	*FAlae*	leaf	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	38
2983	*FAnle*	infl	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2813	*FAnle*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3064	*FAppr*	infl	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0
2969	*FAppr*	leaf	0	7	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
2992	*FBrme*	infl	0	2	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0
2968	*FBrme*	leaf	0	16	0	11	0	0	1	0	0	0	0	0	0	0	18	0	0	0	0	1	0	0	0	0	3	0	0	0
2993	*FBrmi*	infl	0	1	0	0	0	0	0	0	0	0	0	0	19	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0
2945	*FBrmi*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2910	*FBrla*	infl	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	13	0	0	0	0	0	0
2943	*FBrla*	leaf	0	1	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2911	*FBrse*	infl	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	6	0	0	0	0	0	0	0	0
3065	*FBrse*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2805	*FCain*	leaf	0	0	0	0	0	0	47	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
2804	*FCari*	leaf	0	2	0	0	0	0	8	0	0	0	0	0	9	15	9	0	0	0	0	5	0	0	0	1	0	0	0	0
2914	*FCawe*	infl	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2986	*FCawe*	leaf	0	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2988	*FDeca*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
2794	*FDeca*	leaf	0	1	0	0	0	0	0	0	0	0	0	0	0	0	34	0	0	0	2	0	0	0	0	0	0	0	0	0
2916	*FDifl*	infl	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2796	*FDifl*	leaf	0	19	0	0	0	0	0	0	0	0	0	0	5	0	15	0	0	0	0	11	0	0	0	0	0	0	0	0
2792	*FDimi*	leaf	11	32	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2917	*FDipe*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 3E: ANDEAN GRASS COUNT DATA CONTINUED

FESTUCOID			Cat. 1			Cat. 2																Cat. 3								
			SIMPLE			CONICAL																RONDEL								
MU#.	Taxa	Part	Lobed	Rondel	Saddle	2A	2Aa	2Ab	2B	2Ba	2C	2Ca	2Cb	2Cc	2D	2Da	2E	2Ea	2Eb	2Ec	2F	3A	3Aa	3Ab	3Ac	3Ad	3Ae	3Af	3Ag	3Ah
3066	*FDipe*	leaf	0	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2821	*FElco*	infl	0	2	0	3	0	0	0	0	2	0	0	0	2	0	0	0	0	0	13	0	0	0	0	0	0	0	0	30
2947	*FElco*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2820	*FEler*	infl	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6	0	0	0	0	2
2946	*FEler*	leaf	0	33	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	3
2825	*FFedo*	infl	0	0	0	0	0	0	9	0	0	0	0	0	0	0	10	0	0	0	10	0	0	0	0	0	0	0	11	0
2951	*FFedo*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0
2823	*FFeg*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2949	*FFegl*	leaf	0	9	0	7	0	0	0	4	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	6
2824	*FFesu*	infl	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	18	0	0	0	0	0	0	0	16	0
2950	*FFesu*	leaf	0	22	0	10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2919	*FHire*	infl	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2953	*FHire*	leaf	0	25	0	0	0	0	1	0	0	0	0	0	14	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
2952	*FKoku*	leaf	0	26	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
2974	*FMead*	infl	0	31	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
2954	*FMead*	leaf	0	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2976	*FMesc*	infl	0	7	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2955	*FMesc*	leaf	0	49	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2830	*FNabr*	infl	0	26	0	0	0	0	0	0	4	0	0	0	3	0	0	2	0	0	0	15	0	0	0	0	0	0	0	0
2956	*FNabr*	leaf	7	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
2982	*FNapu*	infl	0	24	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2957	*FNapu*	leaf	15	30	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2975	*FOrer*	infl	0	0	0	6	0	0	0	0	0	0	0	4	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2959	*FOrer*	leaf	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2835	*FPist*	infl	2	2	0	0	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2833	*FPist*	leaf	23	5	0	0	0	0	0	1	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2836	*FPone*	infl	0	48	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2847	*FPone*	leaf	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	0	0	0	0	0	2
2981	*FPufr*	infl	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3067	*FPufr*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2839	*FStic*	infl	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 3E: ANDEAN GRASS COUNT DATA CONTINUED

			Cat. 1			Cat. 2																Cat. 3								
FESTUCOID			SIMPLE			CONICAL																RONDEL								
MU#.	Taxa	Part	Lobed	Rondel	Saddle	2A	2Aa	2Ab	2B	2Ba	2C	2Ca	2Cb	2Cc	2D	2Da	2E	2Ea	2Eb	2Ec	2F	3A	3Aa	3Ab	3Ac	3Ad	3Ae	3Af	3Ag	3Ah
2844	*FStic*	leaf	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2838	*FStob*	infl	0	0	0	0	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
2845	*FStob*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	1	0	0	0	0	0	0	0
2841	*FTrsp*	infl	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2842	*FTrsp*	leaf	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2920	*FVumy*	infl	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	0	0	0	0	0	0	0	0	0	0	0
3068	*FVumy*	leaf	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22	0	0	0	0	0	0	0	0
TOTAL FESTUCOID			58	1235	5	82	0	11	69	6	59	2	0	20	391	15	223	4	130	2	160	145	46	21	6	1	3	1	27	109
CHLORIDOID																														
2985	*CAece*	infl	12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2973	*CAece*	leaf	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2915	*CChsi*	infl	0	8	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2942	*CChsi*	leaf	0	5	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2935	*CErci*	infl	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2961	*CErci*	leaf	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2934	*CErme*	infl	0	20	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2960	*CErme*	leaf	4	4	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2958	*CMiin*	leaf	0	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2909	*CMume*	infl	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2944	*CMume*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2939	*CSppy*	infl	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2965	*CSppy*	leaf	12	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2938	*CSpvi*	infl	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2964	*CSpvi*	leaf	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2843	*CTrst*	leaf	0	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL CHLORIDOID			79	273	276	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

APPENDIX 3E: ANDEAN GRASS COUNT DATA CONTINUED

			Cat. 1			Cat. 2																Cat. 3								
PANICOID			SIMPLE			CONICAL																RONDEL								
MU#.	Taxa	Part	Lobed	Rondel	Saddle	2A	2Aa	2Ab	2B	2Ba	2C	2Ca	2Cb	2Cc	2D	2Da	2E	2Ea	2Eb	2Ec	2F	3A	3Aa	3Ab	3Ac	3Ad	3Ae	3Af	3Ag	3Ah
2987	*PAnbi*	infl	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
521	*PAnbi*	leaf	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2801	*PAnse*	leaf	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2979	*PAnte*	infl	18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2802	*PAnte*	leaf	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2822	*PErav*	infl	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2948	*PErav*	leaf	28	6	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2936	*PPara*	infl	8	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2962	*PPara*	leaf	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PANICOID			245	166	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARUNDINOID																														
2912	*ACobi*	infl	0	7	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	13
2798	*ACobi*	leaf	49	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2918	*ACoha*	infl	11	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0
2797	*ACoha*	leaf	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL ARUNDINOID			93	18	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	29	0	0	0	0	0	0	0	13
HIGHLAND MAIZE																														
3069	*MZemaC*	husk	42	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
3070	*MZemaC*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	5
3071	*MZema*	husk	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
3072	*MZema*	infl	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3073	*MZemaSC*	infl	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0
3075	*MZemaCP*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0
3076	*MZemaH*	infl	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
3077	*MZemaPH*	infl	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
3078	*MZemaPC*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0
TOTAL MAIZE			67	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	86	5	0	0	0	0	0	0	10

KEY: All grass scientific names were abbreviated. The first letter corresponds to grass category (I.e. F=Festucoid), the second two letters correspond to genus, the next two correspond to species, and the last two correspond to plant part. Full taxa listing can be found in Appendix 3B.

APPENDIX 3E: ANDEAN GRASS COUNT DATA

FESTUCOID

			Cat. 3 Cont.											Cat. 4				Cat. 5								Cat. 6		Cat. 7			
			RONDEL Cont.											SQUARE				LOBED								SADDLE		OTHER			
MU#.	Taxa	Part	3Ai	3Aj	3Ak	3Al	3B	3Ba	3Bb	3Bc	3Bd	3Be	3Bf	4A	4B	4Ba	4Bb	5A	5B	5C	5Ca	5D	5Da	5E	5F	6A	6B	7A	7B	7C	TOTAL CT.
2980	*FAcacIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2816	*FAcacLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	43
2984	*FAgbrIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2972	*FAgbrLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
2990	*FAgtoIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2817	*FAgtoLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
2991	*FAlaeIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2970	*FAlaeLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2983	*FAnleIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
2813	*FAnleLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
3064	*FApprIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
2969	*FApprLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
2992	*FBrmeIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2968	*FBrmeLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2993	*FBrmiIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2945	*FBrmiLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2910	*FBrlaIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
2943	*FBrlaLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
2911	*FBrseIN*	infl	0	0	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
3065	*FBrseLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2805	*FCainLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2804	*FCariLF*	leaf	0	0	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55
2914	*FCaweIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
2986	*FCaweLF*	leaf	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
2988	*FDecaIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2794	*FDecaLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37
2916	*FDiflIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2796	*FDiflLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2792	*FDimiLF*	leaf	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2917	*FDipeIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50

APPENDIX 3E: ANDEAN GRASS COUNT DATA CONTINUED

FESTUCOID

			Cat. 3 Cont.											Cat. 4				Cat. 5								Cat. 6		Cat. 7			
			RONDEL Cont.											SQUARE				LOBED								SADDLE		OTHER			
MU#.	Taxa	Part	3Ai	3Aj	3Ak	3Al	3B	3Ba	3Bb	3Bc	3Bd	3Be	3Bf	4A	4B	4Ba	4Bb	5A	5B	5C	5Ca	5D	5Da	5E	5F	6A	6B	7A	7B	7C	TOTAL CT.
3066	*FDipeLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2821	*FElcoIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
2947	*FElcoLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2820	*FElerIN*	infl	0	0	0	0	0	0	0	9	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2946	*FElerLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2825	*FFedoIN*	infl	0	0	0	8	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2951	*FFedoLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	51
2823	*FFeglN*	infl	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2949	*FFeglLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2824	*FFesuIN*	infl	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
2950	*FFesuLF*	leaf	0	0	0	15	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
2919	*FHireIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2953	*FHireLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2952	*FKokuLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	50
2974	*FMeadIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2954	*FMeadLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60
2976	*FMescIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2955	*FMescLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2830	*FNabrIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2956	*FNabrLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
2982	*FNapuIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2957	*FNapuLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2975	*FOrerIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	51
2959	*FOrerLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	50
2835	*FPistIN*	infl	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
2833	*FPistLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	53
2836	*FPoneIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2847	*FPoneLF*	leaf	0	0	0	1	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48
2981	*FPufrIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
3067	*FPufrLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2839	*FSticIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50

APPENDIX 3E: ANDEAN GRASS COUNT DATA CONTINUED

			Cat. 3 Cont.											Cat. 4				Cat. 5								Cat. 6		Cat. 7			
FESTUCOID			RONDEL Cont.											SQUARE				LOBED								SADDLE		OTHER			
MU#.	Taxa	Part	3Ai	3Aj	3Ak	3Al	3B	3Ba	3Bb	3Bc	3Bd	3Be	3Bf	4A	4B	4Ba	4Bb	5A	5B	5C	5Ca	5D	5Da	5E	5F	6A	6B	7A	7B	7C	TOTAL CT.
2844	*FSticLF*	leaf	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	51
2838	*FStobIN*	infl	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48
2845	*FStobLF*	leaf	0	34	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	5	0	0	0	0	0	0	0	0	0	0	50
2841	*FTrspIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	51
2842	*FTrspLF*	leaf	0	0	0	0	0	0	30	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2920	*FVumyIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
3068	*FVumyLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
TOTAL FESTUCOID			3	36	4	114	0	2	38	30	31	0	0	3	10	5	22	0	0	45	0	15	0	0	0	0	0	2	5	1	3197
CHLORIDOID																															
2985	*CAeceIN*	infl	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	23	0	0	0	0	0	51
2973	*CAeceLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2915	*CChsiIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2942	*CChsiLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2935	*CErciIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	50
2961	*CErciLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	50
2934	*CErmeIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2960	*CErmeLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2958	*CMiinLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2909	*CMumeIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2944	*CMumeLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2939	*CSppyIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2965	*CSppyLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2938	*CSpviIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2964	*CSpviLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2843	*CTrstLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	50
TOTAL CHLORIDOID			0	0	0	5	0	0	0	0	0	0	0	0	10	13	0	6	0	0	8	0	0	0	23	0	9	0	0	0	803

APPENDIX 3E: ANDEAN GRASS COUNT DATA CONTINUED

			Cat. 3 Cont.											Cat. 4				Cat. 5								Cat. 6		Cat. 7			
PANICOID			RONDEL Cont.											SQUARE				LOBED								SADDLE		OTHER			
MU#.	Taxa	Part	3Ai	3Aj	3Ak	3Al	3B	3Ba	3Bb	3Bc	3Bd	3Be	3Bf	4A	4B	4Ba	4Bb	5A	5B	5C	5Ca	5D	5Da	5E	5F	6A	6B	7A	7B	7C	TOTAL CT.
2987	*PAnbiIN*	infl	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
521	*PAnbiLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2801	*PAnseLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2979	*PAnteIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	12	0	0	0	0	0	0	0	50
2802	*PAnteLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	51
2822	*PEravIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2948	*PEravLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	50
2936	*PParaIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2962	*PParaLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
TOTAL PANICOID			0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	3	5	0	2	12	0	0	2	0	0	0	0	451
ARUNDINOID																															
2912	*ACobiIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2798	*ACobiLF*	leaf	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
2918	*ACohaIN*	infl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
2797	*ACohaLF*	leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	53
TOTAL ARUNDINOID			0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	204
HIGHLAND MAIZE																															
3069	*MZemaCHU*	husk	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
3070	*MZemaCIN*	infl	0	0	0	17	0	0	0	23	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
3071	*MZemaHU*	husk	0	0	3	0	0	0	0	16	0	0	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	51
3072	*MZemaIN*	infl	0	0	0	3	0	0	0	3	0	12	11	0	3	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	50
3073	*MZemaSCIN*	infl	0	0	0	5	0	0	0	23	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49
3075	*MZemaCPIN*	infl	0	0	0	11	0	0	0	12	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
3076	*MZemaHIN*	infl	0	0	0	8	0	0	0	4	0	2	30	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	51
3077	*MZemaPHIN*	infl	0	0	0	0	0	0	0	1	0	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
3078	*MZemaPCIN*	infl	0	0	0	13	0	0	0	1	0	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
TOTAL MAIZE			0	0	3	57	0	3	0	83	0	21	93	0	3	0	0	1	0	17	0	0	0	0	0	0	0	0	0	0	455