Toward a Grammar of the Inka Khipu: Investigating the Production of Non-numerical Signs

Toward a Grammar of the Inka Khipu: Investigating the Production of Non-numerical Signs

A dissertation presented

by

Jon Clindaniel

to

The Department of Anthropology

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in the subject of

Anthropology

Harvard University

Cambridge, Massachusetts

December 2018

Dissertation Advisor: Professor Gary Urton Jon Clindaniel

Toward a Grammar of the Inka Khipu: Investigating the Production of Non-numerical Signs

Abstract

Inka khipus were a unique pre-Columbian semiotic technology that used three-dimensional signs–primarily knots, cords, and colors–as symbols functionally akin to those of writing systems in other cultures. Spanish chroniclers reported that khipus recorded everything from census records, to histories, and songs. Numerical Inka khipu signs were deciphered in the 1920s. However, scholars still have not deciphered any non-numerical Inka khipu signs, nor have they empirically demonstrated how such signs would have worked—whether as phonetic signs, individualized mnemonic devices, or types of semasiographic signs. I demonstrate that non-numerical khipu signs worked as Peircean dicent symbolic legisigns (dicent symbols, or predicates) in binary, hierarchical pairs. Furthermore, I argue that these paired legisigns were conventionalized across the Inka Empire, but circumscribed by genre and political geography. Over the course of my analysis, I decipher several non-numerical signs and demonstrate their use in Inka khipus. Finally, building on my findings from individual signs, I outline a preliminary grammar of the Inka khipu.

Contents

List of Tables

List of Figures

Acknowledgments

This dissertation would not be possible without all of the encounters I have had over the years with brilliant people across a variety of disciplines—mathematics, statistics, computer science, anthropology, and philology, just to name a few—at Harvard and the University of Chicago. As a result, there are so many more people that I am indebted to than I could ever hope to thank in a humble acknowledgements section. I would, however, like to draw attention to some of my most proximate levels of indebtedness.

First of all, I would like to thank Gary Urton, my dissertation advisor and mentor, for encouraging me to move my digital archaeological research to the study of khipus and for his tireless support of this dissertation project. Gary is the consummate advisor and I am very thankful I have had the opportunity to learn from him.

In the collection of archaeological field data for this dissertation, I would also like to thank Alejandro Chu, the director of the Proyecto Arqueológico Incahuasi, for supporting me in the field as an excavator at Inkawasi in 2016. Additionally, my fellow archaeological staff members at Inkawasi—Manuel Calongos, Diana Carhuanina, and Daniel Davila—were second to none and this dissertation would not be possible without their efforts in the field. I am also grateful for Patricia Landa and her painstaking work conserving the Inkawasi khipus. I greatly appreciate her hosting me as well in her home laboratory while I studied the Inkawasi khipus and related materials. I would furthermore like to thank Yazmin Gómez Casaverde and Julio Miguel Saldaña for assisting me in analyzing this khipu material.

In the writing of this dissertation, I am grateful for my dissertation committee members and their helpful comments on various drafts of my dissertation. Sabine Hyland provided useful feedback on an early draft of Chapter 5 and on my treatment of post-conquest khipus throughout the dissertation. Bruce Mannheim made invaluable suggestions with regard to my discussion of semiotic theory and the Quechua language. Jeff Quilter gave insightful comments about the broader Andean archaeological context throughout the dissertation process. Rowan Flad's comments and critique bolstered my treatment of how khipu production fits into archaeological production theory more generally. Oliver Knill provided discerning comments about the mathematical components of my research. Outside of my dissertation committee, I would additionally like to thank Jeff Splitstoser for his willingness to share some of his deep knowledge about Andean wrapped sticks with me early in my Inkawasi wrapped stick analysis, the results of which I have incorporated into Chapter 4 of my dissertation. Also, I thank Manuel Medrano for reading and commenting on an earlier draft of this dissertation. Any errors in the dissertation are, of course, my own.

Finally, I would like to thank my parents, Steve and Karen Clindaniel, as well as my extended family for their ongoing support throughout the process of me completing my doctorate. It has been a long road and I appreciate the sacrifices they have made in order to make my academic aspirations a reality.

Chapter 1

Introduction to Non-Numerical Khipu Signs

1.1 Introduction

> *ce n'est point en effet connaître un système d'écriture, si l'on n'a fait que déterminer la signification de quelques caractères ou groupes de caractères pris isolément dans un texte, sans savoir toutefois par quel moyen, par quelle loi de convention, ces caractères ou ces groupes peuvent exprimer l'idée dont on les suppose les signes écrits; quand on ignore si ces caractères ou ces groupes peuvent exprimer l'idée dont on les suppose les signes écrits; quand on ignore si ces caractères, ces groupes, sont idéographiques ou phonétiques, c'est-à-dire, s'ils expriment directement l'objet de l'idée, ou bien le son du mot signe de cette même idée dans la langue parlée.* (Champollion 1824:10)

In 1822, Champollion arrived at an initial decipherment of Egyptian hieroglyphs based primarily on his interpretations of the Rosetta Stone (Bard 2015:36; Champollion 1822). Importantly, he recognized the writing system as being partially composed of phonetic signs. Champollion toiled until 1824, however, to arrive at a more systematic decipherment and to work out the beginnings of an ancient Egyptian grammar. With his *Precis*, he realized that the only way to make systematic claims about the nature of Egyptian hieroglyphs was by demonstrating that the Egyptians employed widespread conventions across all of the discovered corpus of hieroglyphic texts. In this way, Champollion showed that isolated instances of deciphered hieroglyphic signs were part of a more general set of conventions that phonetically recorded the ancient Egyptian language (Champollion 1824:11). The keys to systematic decipherment were, first, an identification that Egyptian hieroglyphs contained phonetic signs, and importantly, second, the demonstration that the signs were used in widely conventionalized ways.

Today, Inka khipu scholars find themselves at a pivotal moment, much as Champollion did heading into 1822. No one has empirically demonstrated that non-numerical Inka khipu signs were of a particular type: phonetic or otherwise. Furthermore, outside of numerical signs, Inka khipu signs have never been shown empirically to have been used in widely conventionalized ways. While there has been a great deal of speculation on both issues, their lack of resolution has made any attempts to systematically decipher Inka khipus difficult if not impossible. However, Sabine Hyland recently succeeded in identifying the meanings and uses of isolated, post-conquest signs (Hyland 2014; Hyland et al. 2014; Hyland 2016; Hyland 2017). In addition, Gary Urton and Manny Medrano have found and utilized what they suggest might be the "Rosetta Khipu": a match between the content of a Spanish colonial document and a post-conquest khipu archive (Urton 2015, Medrano and Urton 2018). While identified signs thus far are from post-conquest khipus, the work of Hyland, Urton, and Medrano provides a springboard for investigating Inka khipu signs and beginning the same process of systematic decipherment for Inka khipus that Champollion pursued in the early 1820s for Egyptian hieroglyphs.

If we can demonstrate that the Inka employed signs in a similar way as post-conquest khipu specialists whose signs have been deciphered, then it will also be possible to recognize the types of signs used in Inka khipus and evaluate the scale at which these signs were conventionalized. For the remainder of this dissertation, I will pursue this line of research, empirically investigating whether Inka khipu signs worked in the same way as identified post-conquest khipu signs. Through this post-conquest comparison, I will identify sign type(s) used to signify non-numerical information in Inka khipus. Furthermore, I will assess whether the signs I identify were widely conventionalized by the Inka, starting the process of empirically addressing how conventionalized Inka khipu signs were in general. Both research questions together will contribute toward better explicating how Inka khipu signs were generally made and interpreted, forming the foundation for a grammar of the Inka khipu. This research not only has important implications for deciphering non-numerical Inka khipu signs, but also for understanding how the semiosis of a complex recording system other than writing fulfilled the administrative needs of an expansive and dominant empire. In addition, by evaluating the scale of Inka khipu sign conventionalization, my research provides an important view into the strategies employed in Inka administrative statecraft.

Before I begin my investigation, however, I will briefly discuss in the remainder of this introductory chapter who the Inka were, as well as how they were politically, economically, and spatially structured–providing background information that is essential for understanding how the Inka represented themselves through khipu signs. I will also discuss what an Inka khipu is, and how scholars believe khipus signified information. Then, in Chapter 2, I will go into more depth on how I will identify whether identified post-conquest khipu signs were used in Inka khipus, as well as how I will assess their scale of conventionalization. Specifically, I provide a definition of what a sign is and how signs can vary. Using this definition of a sign, I discuss how I will assess whether the Inka also produced signs like post-conquest khipu specialists through archaeological excavation and statistical analysis of extant archaeological khipus in the Harvard Khipu Database. Furthermore, I address how identifying Inka signs in this way will help me answer my first research question of what types of signs Inka khipukamayuqs produced and how these signs worked. Following my discussion of Inka khipu sign production, I focus on how the concept of production "scale" can be adapted to interpret whether Inka khipu specialists produced widely conventionalized signs, in accordance with my second main research question. Then, in Chapters 3 through 5, I answer these two fundamental questions for three specific Inka khipu sign vehicles—knot direction, cord color, and color patterns—through a combination of statistical analysis of the Harvard Khipu Database and archaeological excavation at the Inka storehouse site of Inkawasi, on the Southern Coast of Peru in the Cañete Valley. Finally, I conclude in Chapter 6 with a synthesis of my findings about how non-numerical Inka khipu semiosis worked—that is, a preliminary grammar of Inka khipu signs.

1.2 The Inka Empire: Tawantinsuyu

Archaeological evidence suggests that the Inka began to emerge as a power in the highlands of Peru as early as 1000 CE (D'Altroy 2015:69). By the mid-15th century, the Inka had ascended to a position of dominance over their surrounding neighbors in the Cuzco Valley and continued their rapid expansion throughout the whole of the Andean region, until Spanish conquest in 1532 (D'Altroy 2015:69). The Inka called their own empire *Tawantinsuyu*, or "the four parts together" in the Quechua language—the *lingua franca* of the empire—where each "part" of the empire was called a *suyu* (Figure 1.1).

Figure 1.1: *Map of the Inka Empire: Approximate extent of Tawantinsuyu, superimposed on modern political boundaries (Left), Approximate boundaries of the four Suyus of the Inka (Right)*

Each of the *suyu* regions radiated out from the Inka capital city of Cuzco as quadrants: *Cuntisuyu* (the southern coast of modern Peru, west of Cuzco), *Chinchaysuyu* (the northern portion of the empire, extending through modern Ecuador and into southern Colombia), *Antisuyu* (the eastern portion of the empire, extending into the Amazonian jungle), and *Collasuyu* (the southern portion of the empire, extending through the modern Bolivian altiplano as well as sections of Chile and northwest Argentina).

The Inka royal family was centered at Cuzco, which acted as the cosmological, political and economic center of Tawantinsuyu. The city itself was structured in a binary, hierarchical way that mirrored the organization of many other elements throughout the empire (and brought together binary themes from earlier Andean ruling ideologies). Cuzco was spatially divided between *hanan*, or "upper" Cuzco and *hurin*, or "lower" Cuzco (Urton and von Hagen 2015:5). Those who lived in upper Cuzco were said to have ritual priority to those in lower Cuzco. Emphasizing this spatial division even further, the families of the six most recent Inka rulers had estates in upper Cuzco, and families of the five more temporally distant Inka rulers lived in lower Cuzco. The four suyus were similarly hierarchically ranked in relation to one another, with Chinchaysuyu and Antisuyu corresponding to the upper-ranked hanan portion of Cuzco and Cuntisuyu and Collasuyu corresponding to lower-ranked hurin portion of Cuzco (Zuidema 2015:62). Such a dual mode of organization was a common approach to Andean spatial organization around the time of conquest, even in smaller villages (Urton and von Hagen 2015:5). Thus, this logic of dual, hierarchical social and spatial structures would have been intimately familiar to Inka imperial subjects. Furthermore, the logic of dual, hierarchical pairings plays an important role in the interpretation of Inka khipu signs, a role that I will elaborate on later in this chapter and throughout the dissertation.

Within each suyu, the Inka employed a sophisticated social and economic organization. Ritually, the Cuzco Valley was parceled up into a series of *ceques*–imaginary ritual pathways that connected sacred sites, or *wakas*, leading out from the Temple of the Sun (Coricancha) near the center of Cuzco (Zuidema 2015:62). Each waka corresponded to a day in the Inka ritual calendar, meaning the system simultaneously played a role in organizing ritual space and time. Nine ceque pathways radiated out from Cuzco through each of three suyus: Chinchaysuyu, Collasuyu, and Antisuyu. Cuntisuyu was an exception and contained 14 ceque pathways. These ceques were further ranked by a tripartite hierarchical logic–*collana* ("upper"), *payan* ("middle"), *callao* ("lower")–defining which ranked groups of Inka nobility, or *panacas*, were in charge of caring for and making sacrifices to wakas along a given ceque at the designated time in the Inka ritual calendar (Zuidema 1964:40-42; and 2015:62). Beyond the Cuzco Valley, many towns in Tawantinsuyu were said to have been organized according to ceque systems similar to Cuzco's, corresponding to their own local wakas. Keep this tripartite and quadripartite logic of the suyus and ceque system in mind as we further discuss khipus throughout the dissertation. These modes of ranking social, spatial, and ritual categories become especially important when we discuss the ways in which khipu cord colors carried meaning (see Chapter 4, where we revisit this tripartite and quadripartite logic with a focus on khipus).

The Inka *mit'a* system, a corvée labor tribute system that the Inka used to recruit labor for state projects, served as the primary economic engine for Tawantinsuyu. The labor recruitment system worked by organizing all imperial subjects into various, hierarchical levels of decimal sub-units, each of which had officers and responsibilities for administering the required labor tribute of their subjects (see Table 1.1 for the names and number of subjects recorded at each decimal level).

Table 1.1: *Inka Decimal Organization: Decimal Units from 10 to 10,000.*

Unit name	Number of Tributaries
Hunu	10,000
Pichqa-waranka	5,000
Waranka	1,000
Pichqa-pachaka	500
Pachaka	100
Pichqa-chunka	50
Chunka	10

The first decimal unit at the lowest level of administrative hierarchy was the *Chunka* level, administering 10 tributaries, going up to the *Hunu* level, that administered 10,000 tributaries (Julien 1988). Administrative records about this labor tribute and organization would have been encoded in khipus, as would the related production, distribution, and storage of goods stored in state storehouses around Tawantinsuyu.

While this idealized, ranked quadripartite description of the empire may make it seem as if the Inka exerted top-down control over their entire empire, the on-the-ground reality is that the Inka pursued a variety of both direct and indirect imperial strategies to maintain and expand their empire. Different parts of the empire were conquered by the Inka at different times and often administered in radically different ways depending on the local environmental, political, cultural, and economic context (Covey 2000:120). For instance, within the Collasuyu region to the south of Cuzco, the Inka administered the region between Arequipa in Peru and Tarapacá in Chile as a distinct administrative region called *Colesuyu*, with only a limited amount of control (Covey 2000:122; Rostworowski 1986:127). Instead of establishing a system of direct rule in the region, Colesuyu was only loosely integrated into the empire via roads and a series of *tambos* (way-stations) that stretched all the way down what is today the north coast of Chile to form a connection with important copper and turquoise mines to the South (Rivera 1991:38-39). Thus, we must keep in mind that, while the aforementioned structure of the Inka empire was the ideal, the Inka readily made adjustments to account for the on-the-ground realities of ruling such a vast territory.

Around the world, empires relied on sophisticated recording systems to record such far-flung economic, demographic, and ritual information as that which formed the substance of the Inka administration. The Inka were no different, administering and recording information about their vast empire using khipus. For the remainder of this chapter, I will discuss what an Inka khipu is in greater detail, as well as the ways in which scholars believe khipus signified information.

1.3 An Inka Khipu Sign Primer

Whereas a written document, like the one you are reading now, signifies using two-dimensional signs, khipus employed three-dimensional knot-and-cord-based signs to signify information. The Inka utilized this unique semiotic technology to record everything from storehouse accounting, to histories, calendars, and songs (Ascher and Ascher 1997:74; Urton 2003:3).

Khipukamayuqs–those who made and interpreted khipus (Quechua: "knot makers, organizers, or animators")–utilized a rich array of cord-based signs to encode information in khipus. To produce signs, Inka khipukamayuqs attached differently colored, plied, and knotted cords onto a single primary cord that held all of the cords together in a specified order (Conklin 2002, See Figure 1.2 for an illustration of the physical features of an Inka khipu). At one end of the primary cord, there is frequently a knot, tassel, or "end ornament" bundle (called the "end knot" in Figure 1.2) and on the other end of the primary cord there is often extra, dangling cord (Urton 2003:4–5).

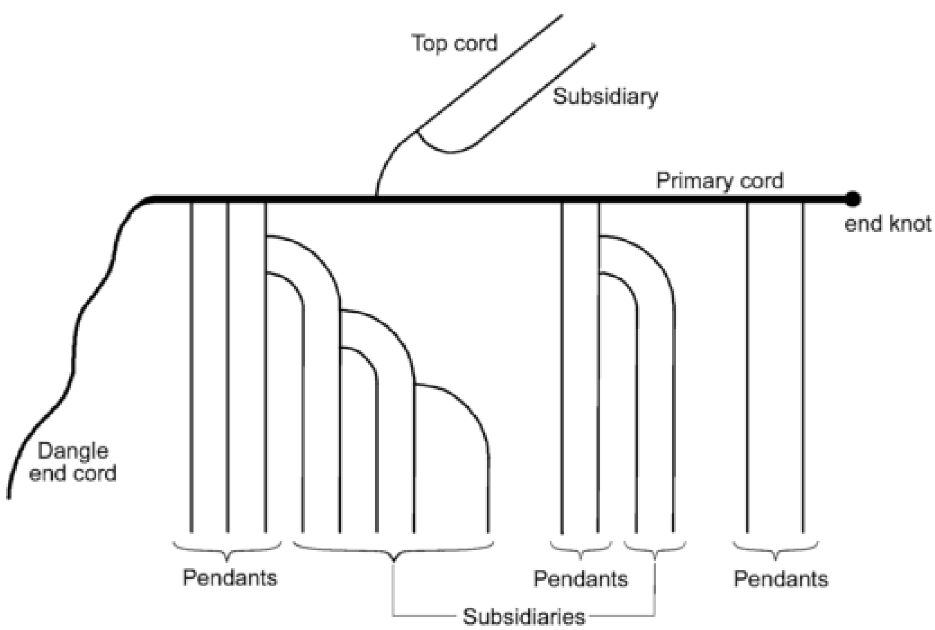


Figure 1.2: *Physical Features of an Inka Khipu (from Urton 2003: 4)*

Cords attached to the primary cord are called "pendant cords" and further cords attached to these pendant cords are called "subsidiary cords" (to which, further subsidiary cords may be added). In addition, khipukamayuqs sometimes tied cords called "top cords" above groups of pendant cords to record aggregate sums of the numbers signified on pendant cords below. Numbers were signified on cords in a decimal notation, with units in the 1's place being closest to the end of an attached cord, farthest away from the primary cord. Each subsequent decimal place value (10's, 100's, etc.) was placed at standard increments higher up the attached cord, closer to the primary cord (Locke 1923, see left-most panel of Figure 1.3). Three knot types were used to signify specific numerical values at different decimal positions on a cord (see right-most panel of Figure 1.3).

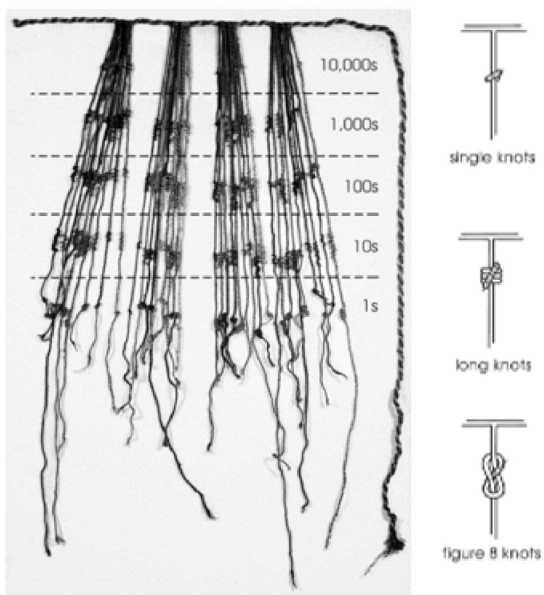


Figure 1.3: *Signifying Numbers on an Inka Khipu; Left: Khipu decimal notation (Urton 2003:8), Right: Three knot types used in Inka khipus for numerical signification (Urton 2003:77)*

Figure-eight and long knots were utilized solely to signify numbers in the 1's position. Figure-eight knots were only used to signify the value "1," whereas long knots could signify larger numbers in the 1's position (2, 3, 4, 5, 6, 7, 8, 9) based on how many times the attached cord was wrapped around itself before being tied off into the long knot. Thus, if a pendant cord solely featured a long knot wrapped 3 times around the cord, its numerical value would be “3” (see Figure 1.4, left-most cord). Single overhand knots were used exclusively in the tens and higher places and could be grouped together at a particular decimal place position. Therefore, if a cord solely featured two single overhand knots in the 10s place, this would signify “20” (see Figure 1.4, second cord from the left). If a cord solely featured two single overhand knots in the 100s place, this would signify “200” (Figure 1.4, third cord from the left). A number featuring values at multiple decimal positions could be signified by employing knots at each one of the respective positions. Thus, a cord with two single overhand knots in the 100s place, two single overhand knots in the 10s place, and a long knot wrapped three times around a cord, would have the overall value “223” (Figure 1.4, right-most cord).

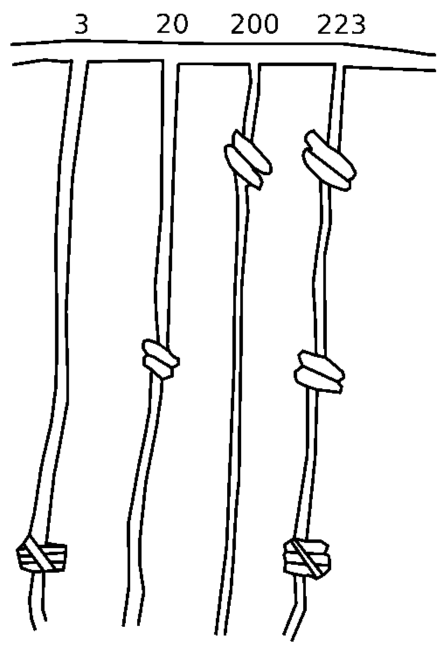


Figure 1.4: *Illustration of Inka Numerical Notation*

Khipus using this standard numerical notation did not just record data in a vacuum, though. They recorded numerical information *about something*. For the most part, however, it remains a mystery to khipu scholars how khipukamayuqs recorded what their numbers referred to. Nonetheless, scholars have recognized that, in addition to numerical signs, there were a wide variety of other physical features on Inka khipus that could signify information, such as cord color, the ply direction of a cord, and even the way in which a pendant cord was attached to its primary cord. Based on these physical features, Inka khipus could have stored thousands of distinct semantic values—an expressive capacity akin to early cuneiform (Urton 2003:117–118). Inka khipukamayuqs are thought to have used these features to signify information in addition to the numerical values recorded on khipu cords—giving numbers context and qualitatively denoting what the numbers were about. Throughout this dissertation, I specifically refer to such signifying features as "non-numerical signs," by which I mean signs supplementary to the knot-based numerical system discussed previously.

With such a large information capacity, the first natural question to ask is whether or not Inka khipu signification was in fact a form of writing, as we see in use in other major polities around the world. Because of the uniqueness of the khipu semiotic medium, however, the question is not as straight-forward as it might at first appear. The linguist and scholar of writing John DeFrancis, for instance, states that "speech underlies all real writing" and that "real writing" is that which "permits and expresses any and all thought" (1989:47). In other words, under this commonly used definition, the key to writing is the capacity for phonetic signification.

While Urton argues that "narrative" khipus could have encoded phonetic values just as writing systems do (2002:190) and might be expected to have done so in the case of encoding verb forms (1998:425), no one has provided empirical evidence that Inka khipukamayuqs actually used phonetic signs. Specifically, Urton argues that certain "anomalous" khipus–ones that did not record numbers in the standard knot format described above–may have used knots to convey narrative, or even phonetic data (2002). My own analysis shows that the majority of these anomalous khipus still likely recorded numerical information using knots; however, they did so in a different format than the standard Inka numerical notation (Clindaniel 2018). Regardless, anomalous khipu cords constitute only a small subset of extant archaeological khipu cords (8%). The non-numerical signs I focus on in this dissertation are the vastly more common signs associated with khipu cords using standard numerical notation, as demonstrated in Figure 1.4.

Other authors, however, argue that sign systems do not need to have a preference for orality or phonetic signification in order to be considered writing. Piotr Michalowski, for instance, argues that this sort of orality-priviliged thinking is an "ethnocentric blind spot," inspired by a long history of evolutionary interpretations about the history of writing, where alphabetic writing (like the system we use) is at the top of the food chain (1994:62). Rather than having developed in a steady march towards phoneticism, contemporaneous writing systems employed different amounts of orality, according to the ways in which they were used in a particular society. For hundreds of years, scribes in the Near East continued using cuneiform (which employs logographic–non-phonetic word signs–as well as syllabographic–phonetic syllable–signs) for public display alongside "more phonetic" alphabetic alternatives, like the Aramaic script, for everyday business and administration (Michalowski 1994:59,62-63). For Michalowski, writing systems are thus not defined by their ability to record orality, but as inventions of a new form of human discourse that coexist with other systems of communication and are particularly suited to the unique political and social uses for which they were created (1994:58,64). As such, a particular sign system's capacity for phonetic signification should be considered tangential to its designation as writing or not. Along this more inclusive line of thinking about writing, Elizabeth Hill Boone suggests that writing might better be defined as a society's practice of recording knowledge "by means of graphic or tactile marks that are made on or in a permanent or semipermanent substance...The marks are conventionally understood within their societies to signify objects, events, identities, temporalities, relations, and other concepts and things" (2011:379).

In addition to stepping beyond an ethnocentric account of writing, such a definition as that offered by Boone potentially includes a variety of indigenous American systems of recording as writing. These would include Mesoamerican pictographic systems and Inka khipus, which were functionally used to record information in a similar way as other systems around the world, but did not emphasize the use of phonetic signs to do so. Khipus, for instance, do seem to have employed tactile marks in a semipermanent substance in the form of cord and knot-signs to signify information. Recall, however, that the non-numerical signs of the Inka khipus have yet to be demonstrated to have had conventionalized meanings–an important component of Boone's definition of writing. We will return to this discussion of writing in Chapter 6 and evaluate whether Inka khipus were a writing system after I have empirically evaluated the conventionality of non-numerical khipu signs in Chapters 3, 4, and 5.

But if Inka khipus did not feature phonetic signs, what kind(s) of signs would Inka khipukamayuqs have generally employed in producing non-numerical khipu signs? Frank Salomon argues that semasiographic signs were present in multiple Andean media, and are also the best bet for understanding khipus (Salomon 2001:2). Semasiographic systems–such as mathematical notation, musical notation, and Arabic numerals–all employ signs that stand for their object itself and not for any particular linguistic/phonetic naming of that identity, or value (Sampson 1985:29–31). Under this model, khipus would not have presented information in the sense of the phonetics of a written book. Rather, each khipu as a whole would have been more like an infographic with the capacity to predicate information about a signified entity via other cord-based signs—again, much like early cuneiform (Salomon 2004:281). For instance, a pie chart predicates information about its signified entities via the height, shape, and color of different semicircular slices.

Urton argues that the varying physical features of an Inka khipu could have encoded such predicate information in a binary fashion, following the linguistic concept of "markedness" (Urton 2003:45–48). In markedness relations, categories in binary opposition often exist in a socially primary/secondary relationship, in which unmarked categories are said to be primary to (and inclusive of) marked categories. An example of this phenomenon in the English language is the pair of words "day" and "night." "Day" can be used to refer specifically to daylight hours, but it can also take on a more inclusive meaning of day and night together (i.e. a 24-hour “day”). For instance, if I said, "I will be out of town all day" this would mean that I would be out of town for the entire 24-hour day–including both daylight hours and nighttime hours. "Night," on the other hand, is the marked term in the relationship and is only used in a more exclusive sense to refer to times that are non-daylight hours. If I said, "I will be out of town all night," this specifically means I will be out of town only for nighttime hours. Recall from the introduction to Tawantinsuyu at the beginning of this chapter that this type of hierarchical dualism has been shown to have been present in the Inka world as well. For instance, the Inka spatially divided Cuzco into “upper” and “lower” parts, where the upper, *hanan*, part of Cuzco received ritual priority over the lower, *hurin*, part.

Three recent studies of post-conquest, Colonial-era khipu signs by Sabine Hyland and one based on Medrano and Urton’s “Rosetta Khipu” have demonstrated the use of semasiographic signification and hierarchical dualism in the khipu medium. While these identified signs were produced long after the fall of the Inka empire, they provide evidence that such signs have been used in khipus and are suited to the khipu semiotic medium. Furthermore, careful study of these post-conquest khipu signs has the potential to provide important clues as to how Inka khipu signs functioned as well.

First, let us consider the direction in which khipu cords were plied. Khipu cords have been shown to have been plied from left to right (making the ply direction look like the oblique central line “\” in an “S”) in some cases and right to left in others (making the ply direction look like the oblique central line “/” in a “Z”) (See Figure 1.5).

Figure 1.5: *S- and Z-Ply Direction (Urton 2003:63)*

Furthermore, the yarn being plied together could take on different directions (S and Z) depending on the way in which it was spun. Urton has noted generally, however, that S and Z spun yarn tends to be plied in a corresponding, but opposite, direction (1994:274). Thus, a cord will tend to be S-spun/Z-plied and Z-spun/S-plied. In Urton's discussion of markedness, he notes that Z-spun/S-plied cords occur at a far higher frequency (91.3%) in extant khipus than do S-spun/Z-plied cords (2003:63). Drawing on the work of Joseph Greenberg who suggests frequency provides a good proxy for distinguishing marked and unmarked categories, Urton argues that the more frequent Z-spun/S-plied cords are likely to signify unmarked categories and that S-spun/Z-plied cords are likely to signify marked categories (2003:145).

Up until recently, though, there has never been any direct evidence to support Urton's theory. That is, until Hyland identified a herder's khipu that utilized ply-direction signs (Hyland 2014). The khipu itself was collected in 1895 by Max Uhle at the Cutusuma hacienda in Bolivia. In addition to the khipu, Hyland found written testimony (in Uhle's field notes) about the khipu's meaning from the khipukamayuq who produced it. The khipu itself was a herder's khipu that recorded numbers of sheep and dairy cows. While Uhle himself did not mention ply as a factor, he did label which cords referred to which categories, allowing for post-hoc analysis. Significantly, the distinguishing feature between a grouping of two cords recording female sheep and two cords recording male sheep was ply: S-ply signified female and Z-ply signified male (Hyland 2014:3). A redundant way of specifying this difference was through order, whereby the Z-plied male category always occurred after the S-plied female category. This redundant ordering is reminiscent of the Chronicler Garcilaso de la Vega's claim that when Inka khipu cords were not color coordinated by signified category, they were instead ordered by relative quality—ranked in a culturally significant way (1918[1609]:152). Furthermore, the language of the Inka, Quechua, employs this technique in a variety of different media. Bruce Mannheim argues that the semantic importance of order is a general feature in Quechua poetics, with the first term in a pairing often taking hierarchical precedence to the second (Mannheim 1986:60).

Another grouping of three cords on the Cutusuma khipu represented the hacienda's dairy cows, who were all (of course) female. The direction of ply for these cords corresponded to the milking status of the cows, where a final S ply meant the cows were milked daily (present on one cord) and a final Z ply meant they were not milked daily (this Z ply was present on two cords: both those that were dry and those not milked every day; Hyland 2014:3). Both instances demonstrate the use of semasiographic techniques to produce signs according to markedness relations. In accordance with Urton's theory, the khipukamayuq used S-plied cords to record data from unmarked categories and Z-plied cords to record data from marked categories. When distinguishing gender, the higher ranked category would be the "female" category because females have the capacity to increase the size of the herd (i.e. to reproduce). When distinguishing between different levels of milking, hierarchy was determined based on whether or not the cows were productive or not.

Hyland and her colleagues have also investigated the role of knot direction in post-conquest khipus (Hyland et al. 2014). Single knots, long knots, and figure-eight knots can all be tied either from the top left to lower right (where the knot direction looks like the oblique central line "\" in an "S"), or from the top right to the lower left (where the knot direction looks like the oblique central line "/" in a "Z") (See Figure 1.6).

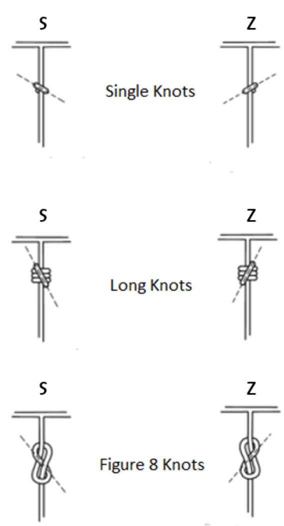


Figure 1.6: *S- and Z-Knots by Knot Type (Urton 2003:77-78)*

In his studies of extant archaeological khipus, Urton has found Z-knots of all three types of knots to be nearly twice as common as S-knots and theorizes that Z-knots were used to signify unmarked categories and S-knots were used to signify marked categories (2003:153). Hyland et al. empirically evaluated this theory by studying a combined alphabetic/khipu cord device called a "khipu board" found in a colonial Catholic Church in the village of Mangas in Ancash Department, Peru that was used in the early 19th century (Hyland et al. 2014). The wooden board is covered in paper and features a series of 282 written personal names (2014:2). Next to each name, a hole has been drilled through the board and an individual khipu cord passes through the hole that is knotted at the end. Boards such as this one were used by the Mercedarian Roman Catholic religious order in Peru to track whether or not individuals in the community fulfilled their religious duties (2014:2). If community members fulfilled their religious duty, their khipu cord was pulled tightly against the board through the hole next to their name and held in place by the end-knot (2014:6). If a person's full khipu cord was still hanging down the front of the board, this indicated they had not completed their religious duty and they were flogged.

When Hyland et al. studied the direction of the end-knots that were still preserved in the Mangas khipu board, they realized that knot direction corresponded with whether or not the named person belonged to the upper or lower moiety in the community (2014:8). Moiety affiliation was determined by ethnographic research in which people today with similar names to those on the khipu board testified as to whether they belonged to the upper or lower moiety. Those names belonging to the upper moiety had an S-knot on the khipu cord next to their name. The names belonging to the lower moiety had a Z-knot on the khipu cord next to their name. Note that while this finding demonstrates Urton's theory that S and Z-knots can be used to signify an unmarked/marked pair of categories, the knots used are the opposite of what Urton predicts. Here, S-knots are unmarked and Z-knots are marked. This divergence might be a matter of post-conquest khipukamayuqs following different knotting conventions, or suggestive of a more complex relationship between S and Z-knot signs. Nonetheless, the Mangas khipu board provides valuable evidence that knot direction has been used by khipukamayuqs to designate marked and unmarked pairs.

The way in which a khipukamayuq attached a pendant cord to a primary cord has also been shown to have signified upper and lower moieties. Pendant cords were made by doubling over an overspun strand of single-ply yarn. When overspun yarn is doubled over, the yarn automatically plies together into a single cord—a completed pendant cord. To attach the pendant cord to the primary cord of a khipu, the khipukamayuq would then take the end of the doubled cord and open up the loop that formed at its end, passing the rest of the pendant cord around the primary cord and through the loop (Conklin 2002:75, see Figure 1.7). This "loop hitch knot" could be tied one of two ways: either by sending the pendant cord through the loop behind the primary cord ("recto"), or in front of the primary cord ("verso") (Urton 2003:70–71).

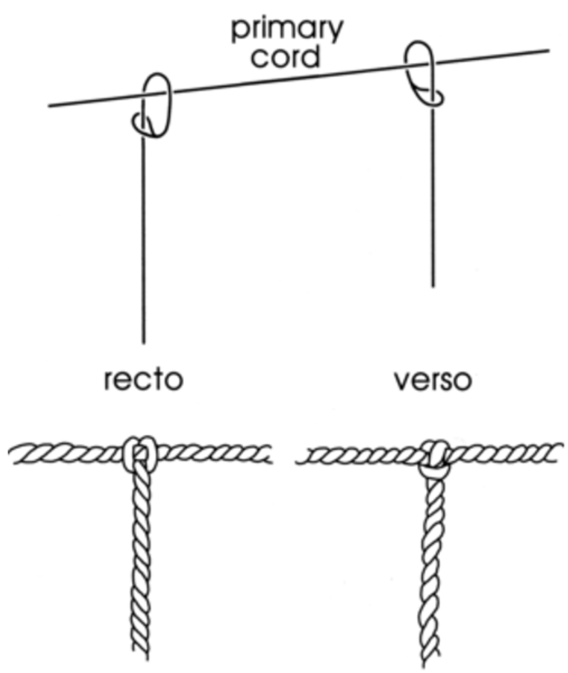


Figure 1.7: *Recto and Verso Pendant Cord Attachment Types (Urton 2003:71)*

Note that the use of the terms "recto" and "verso" is arbitrary. When a khipu is turned over, for instance, values that had been recorded recto would now be verso and verso recordings would now be recto. Recto and verso can therefore only be absolutely determined when the analyst knows the direction in which the khipu was meant to be read. While reading direction is still unknown, khipu scholars conventionally record khipu data from the direction of the primary cord end knot, usually placed to the left, to the dangling end of the primary cord, to the right (see Figure 1.2). Thus, where "recto" and "verso" have been recorded in extant khipus, they are recorded in a conventional manner that allows for comparison of their use across khipus. While attachment type has been noted as a potential khipu sign, no one has demonstrated any clear usage patterns in extant Inka khipus (Urton 2003:72). However, Urton recently found what he calls the "Rosetta Khipu": a set of post-conquest khipus from the Santa Valley in Peru that match a Spanish registry of tribute payers from the region (Urton 2015). Furthermore, he demonstrated that each of the khipus represented one of six ayllus (an Andean clan-like social grouping) in the Santa Valley town of San Pedro de Corongo and that differently colored six-cord groupings of cords within each khipu corresponded to data related to individual tributaries—i.e. (roughly) 132 named individuals in six ayllus and 132 six-cord groups on the set of six khipus (2015:160–161).

Follow-up work on the Santa Valley khipus further indicates that moiety affiliations were encoded using recto and verso attachment types (Medrano and Urton 2018). The Spanish tribute registry only included the names of the 132 members of the six ayllus within the town as well as the number of individuals within each ayllu, but not information on whether the ayllus belonged to upper or lower moieties in the community. However, Medrano and Urton found that two three-ayllu groupings matched the frequency of recto and verso cord attachments on the first pendant cord of each six-cord grouping in the khipus (2018). Therefore, assuming these proposed ayllu groupings did correspond to moieties, post-conquest khipukamayuqs seem to have used recto and verso attachment types to record unmarked and marked categories. However, unlike Hyland's findings for knot and ply direction, it is not known which attachment type would have been considered marked and which unmarked on the basis of these proposed groupings alone. Even so, the Santa Valley khipus provide valuable evidence that attachment type likely has been utilized as a sign for marked and unmarked categories in the khipu semiotic medium.

Finally, Hyland addressed a topic that has been a point of contention since the Spanish chroniclers first wrote about it: the meaning of the different khipu cord colors. While khipu cords are believed, based on Spanish testimony, to have been extensively dyed, the vast majority of extant archaeological khipus seem to have been coded using only the natural colors of the yarn they were made from: the browns, tans, and whites of camelid and/or cotton fibers (Conklin 2002:63). Individual pendant cords could take on multiple colors if yarn of different colors was plied together, forming such complex patterns as those resembling the color spiral of a barber pole, mottled patterns composed of a seemingly random mixing of two or more colors within a cord, or even complete color changes midway through a cord (Conklin 2002:70). But what did these different colors mean for khipukamayuqs?

Garcilaso de la Vega reported that, for the Inka, there was a one-to-one correspondence between cords colored yellow and the metal gold, those colored white and the metal silver, and finally red and warriors (1918[1609]:152). Antonio de la Calancha further added that black signified time, that green stood for Inka troops who died during battle, and red stood for fallen enemy troops, among many other designations (1638:91). However, these chronicler interpretations prove problematic as universal Inka categories when we consider color use across extant khipus. Mackey notes for instance that a large percentage of all khipu cords are white. If Garcilaso was correct in his interpretation of white cords signifying silver, we would expect a wildly unrealistic amount of silver to have been counted by khipukamayuqs (Mackey 1970:57).

Brokaw argues these divergent interpretations may be the result of chroniclers witnessing different levels of semiotic institutionalization or perhaps different khipu genres, but it is difficult to unravel which might be the case (2010:262). Furthermore, given the consistent emphasis on dualistic classification throughout the Andean world, it seems more likely that color signification would also have followed a relational paradigm, rather than the model of one-to-one dictionary signification advocated by the chroniclers (Urton 2003:108). For these reasons, scholars often have instead studied khipu color patterns as a whole. By color patterns, I specifically refer to the pattern of pendant cord colors tied adjacent to one another along the primary cord of a khipu. Khipu scholars have primarily discussed two color patterns: "color seriation" and "color banding" (see Figure 1.8).

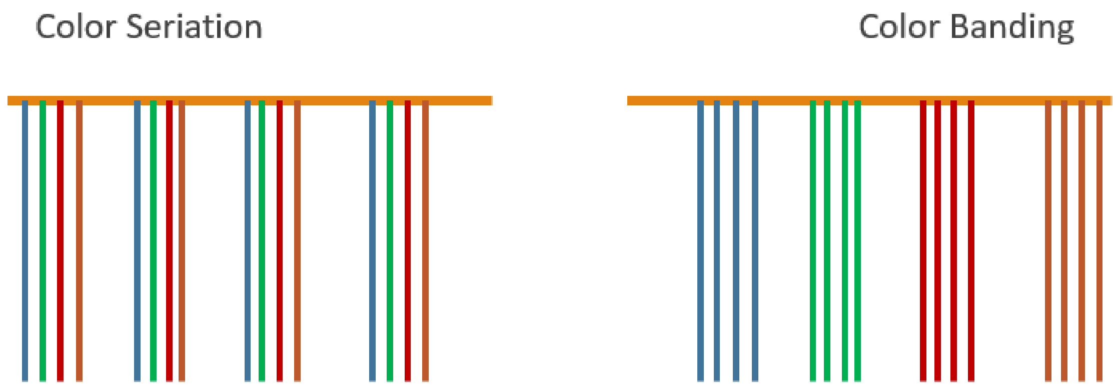


Figure 1.8: *Illustration of Color Seriation and Color Banding*

Color seriated khipus feature a sequence of differently colored pendant cords repeated multiple times within a khipu. Thus, the seriated khipu in Figure 1.8 is a four-color seriated khipu. It features a sequence of blue, green, red, and brown repeated throughout the khipu. Color banded khipus on the other hand are khipus that feature multiple sequences of identically colored pendant cords. The banded khipu in Figure 1.8 is a four-color banded khipu. In contrast to the seriated khipu, the sequence of blue pendant cords forms its own group, the green its own group, the red its own group, and finally the brown its own group. Both forms of color patterning have the capacity to format complicated cross categorizations, whereby both categories and subcategories may effectively be represented by colors and respective color groupings (Ascher and Ascher 1997:82–83). However, identifying these signified categories has long been a mystery in khipu studies and open to speculation.

For instance, Mackey argued that each seriated color grouping in khipus from Puruchuco indicates a separate accounting event of the same color-coded accounting categories (1970:62). While Mackey did not make an attempt at an interpretation of what categories the colors signified and instead favored a mnemonic interpretation, other researchers have made suggestions for possible conventionalized values. For example, based on a four-color seriated patrimonial khipu from Tupicocha, Salomon hypothesized that khipu color sequences were used for planning ayllu labor tasks via four color-coded parameters: date of a labor task, location, name of person, and the tools needed to complete the task (2004:265). Building on Salomon's work, Urton and Brezine suggested that the same type of color-coding may have been used for coding information on the Puruchuco khipus studied earlier by Mackey (2007:377).

There has been no less speculation about banded khipus. Radicati, for instance, argued that banded khipus from the Santa Valley might be conventionalized ideograms in the same sense as Chinese hexagrams (2006:219–220). Under this interpretation, each khipu band hypothetically contained an expression and a combination of khipu bands would have been read in the same way as written text. While ideograms might be otherwise represented in the khipus, Urton has since matched the numbers and banded sequences on these same Santa Valley khipus to a registry of tribute payers from the region (2015). He demonstrated that each of the khipus represented an ayllu registry, whereby the differently colored bands corresponded to the number of tributaries and the individual cords corresponded to classes of data pertaining to people who made up a tributary household (2015:160–161). In his sample of patrimonial khipus from Tupicocha, Salomon argued that banded khipus instead were organized temporally, whereby each band was a task for ayllu members to complete and band position indicated where in the temporal cycle each task fell. Each cord then represented whether or not an individual ayllu member had completed their assigned task, with cords that were still knotted identifying noncompliance on labor tasks (2004:244–250).

Recently, however, Sabine Hyland has developed an empirical model of how these two color patterns could have worked together and what they would have recorded (Hyland 2016). Hyland found unpublished testimony from a khipu expert in the community of Santiago de Anchucaya in Huarochiri Province, Peru about how color seriation worked to record labor contributions in the 1930s and 40s (2016:491). She then compared the testimony to actual contemporaneous banded khipus produced in Anchucaya to determine how color banding would have worked as well. She found in the testimony that contributions towards community tasks at an ayllu group-level were recorded on seriated khipu cords, with each different color in a single-color sequence representing the contribution of the group to a single task (2016:499). This same seriated sequence was then repeated for each task the ayllus were meant to communally complete (so for ten tasks, there would be ten seriated sequences on the khipu). Diverging from Inka khipus, each pendant cord recorded two sets of numbers. The numbers on the top half of each cord recorded quantities of work that had been successfully completed and the numbers on the lower half recorded quantities of work that had not been carried out and was still owed (2016:495). Hyland then interpreted the actual banded khipus to represent the labor contribution of individual moiety-members to their moiety's labor debt–a record that the testimony said was kept at an ayllu level (2016:505). Based on the number of tasks and individuals in the moiety, Hyland inferred that the pendant cords of the banded khipus represented communal labor tasks and the color bands corresponded to individual moiety members (2016:505). If cords still had knots in them, Hyland interpreted this as meaning the task had not been completed since the vast majority of the cords did not have any knots (2016:501). The order of the bands then likely would have followed the order of membership into the moiety (with most senior members coming first) just as occurs in modern notebooks performing the same function. In this way, Hyland demonstrated that in this post-conquest context, color seriation signified that a khipu recorded aggregate, group-level labor data and color banding signified that a khipu recorded individual-level labor data within an ayllu. This finding correlates well with Urton's Santa Valley khipu findings, where banding also corresponds to household or individual ayllu-member data as opposed to aggregated, ayllu-level data. Furthermore, these findings seem to correspond to Urton's theory of markedness, with color seriation recording a higher hierarchical position (unmarked) than color banding (marked).

Thus, in summary, khipu scholars have made headway empirically identifying instances in which post-conquest khipukamayuqs have mobilized non-phonetic, marked-unmarked sign pairings. Such findings open the door for exploration of the signs' potential use as Inka khipu signs. S-knots have been shown to encode unmarked, more-valued categories and Z-knots have been shown to encode marked, less-valued categories in post-conquest khipus (Hyland et al. 2014). S-plied cords have been shown to record unmarked categories and Z-plied cords have been shown to record marked categories (Hyland 2014). Similarly, the way in which pendant cords were attached to their primary cord recorded marked and unmarked categories in the Santa Valley khipus (Medrano and Urton 2018). Furthermore, Hyland has demonstrated the use of a hierarchical, binary pair of color pattern signs for differentiating individual and moiety-level labor contributions in post-conquest khipus produced in Anchucaya (Hyland 2016).

In Chapters 3-5, I will specifically focus on knot direction, cord color, and color pattern signs, seeking to clarify what types of signs these sign vehicles were for the Inka (if any) and whether or not they were widely conventionalized. By extrapolating my findings from these three sign vehicles, I will additionally begin to address what types of signs Inka khipukamayuqs would have generally used to signify non-numerical values as well as the degree to which such signs would have been widely interpretable throughout the Inka empire.

At least for post-conquest khipukamayuqs, the identified signs were more akin to infographic elements than phonetic characters—hinting that such khipus may have generally employed only semasiographic signs and not alternative ones (i.e. phonetic or otherwise). Calling a sign system semasiographic does not fully answer my more fundamental question of what type of signs were used in the Inka khipu sign system, however. The identified post-conquest signs indeed were not phonetic, but what exactly were they? How were they interpreted and how did they convey meaning?

To clarify what types of signs these post-conquest khipukamayuqs (and potentially Inka khipukamayuqs) produced, I turn in Chapter 2 to Peirce's definition of the "sign" in order to address how sign types vary and where the identified post-conquest khipu signs fall in this variation. Careful definition of how these identified signs were constructed and what sign types they belong to is a necessary step in order to fully evaluate whether Inka khipukamayuqs actually produced the same types of signs and not just vague resemblances of the signs produced by post-conquest khipukamayuqs. Furthermore, considering the specifics of these identified signs will aid further decipherment efforts by producing a more nuanced interpretation of khipu semiosis as a whole.

Chapter 2

Identifying the Production of Non-Numerical Inka Khipu Signs

2.1 What Type of Sign is a Khipu Sign?

In order to specify what types of signs the identified post-conquest signs are, I will first define what I mean by the term "sign." The study of the sign is an ancient tradition going back at least to Plato and Aristotle, continuing through later Stoic and Epicurean debates, and into the present day (see Nöth 1990:83–90 for a summary of sign definitions developed by these different schools of thought). In my analysis, however, I specifically employ the semiotic framework of Charles Sanders Peirce.

Peirce (1839-1914) was an American pragmatist philosopher who never gave a complete, systematic explication of his work in a single text. Instead, his ideas were scattered throughout a variety of papers, articles, and letters—continuing to evolve and change over the course of his lifetime. Peirce conceived of his system of semiotics as a foundation for philosophical logic (Savan 1988:1). Thus, he constructed a generalizable semiotic framework, with attention to a variety of different media types, such as phonetic speech, hand signals, diagrams, and much more.

An important component of Peirce's system that allows for this descriptive generality is his emphasis on interpretive practice. Peirce argued that signs are a part of a theoretically unlimited stream of semiosis, and emphasized semiosis as a fluid interpretive process, rather than a static association between a signifier and that which is signified (Savan 1988:1). Peirce defined signs as irreducible triadic relationships between three components: an object, a sign-vehicle (he reuses the term "sign" for this component, but I use the customary term "sign-vehicle" to avoid confusion), and an interpretant. The object is what Peirce sees as the force that drives the semiotic process—that which compels a sign relation in the first place and is represented by a sign-vehicle (Liszka 1996:21). The sign-vehicle is that which stands for its object in some way, whether that be through qualitative, existential, or conventionalized association (Liszka 1996:20; Parmentier 1994:4). The interpretant correlates sign-vehicle and object (i.e. recognizes the sign-vehicle as a sign-vehicle via externally existing grounds) and translates the sign-vehicle into another sign-vehicle (Liszka 1996:24; Parmentier 1994:5). Each interpretant is then itself a sign-vehicle to some further interpretant of the same object, meaning that every interpretant signifies some antecedent interpretant of the same object and the process of semiosis continues indefinitely (Savan 1988:44). The flow of these infinite processes of interpretation is, however, constrained by the material world (the object) as well as cultural regularities (since existing sign-vehicles are previous interpretants) (Hodge and Kress 1988:20). With this emphasis on the relationship between the sign-vehicle and object, Peirce's system allows us to describe sign relations in terms of different levels of conventionality, as well as types of interpretation. In addition, Peirce defined a clear way of analyzing how such signs change over time, with each sign's interpretant always becoming a sign-vehicle for a further semiotic triangle.

Based on the various ways in which the fundamental components of a sign can relate to one another, Peirce described a total of 10 classes of signs in his most complete description of sign relationships (Peirce 1955:101; for information on incomplete descriptions of additional classes of signs, see Savan 1988 and Liszka 1996). Specifically, Peirce constructed three semiotic trichotomies that describe the various relationships that can exist between components of a sign. From these different relationships, there are 27 combinatorial variations of the basic triadic sign, with only 10 of these variations being logical possibilities within Peirce's system (Parmentier 1994:17). I describe Peirce's trichotomies here in detail because his descriptions of possible sign relationships allow me to be extremely specific with respect to what types of signs the identified post-conquest khipu signs might be. This specificity gives me an important starting point for analyzing whether or not Inka khipukamayuqs may have utilized the same types of signs.

Let us begin with arguably Peirce's most famous trichotomy: classifications for the relationship between the object and sign-vehicle (Peirce 1955:102–103). Specifically, Peirce makes a distinction between sign-vehicles that refer to their object via resemblance (icons), sign-vehicles that are actually affected by their object (indices), and sign-vehicles which refer to their object in a primarily conventional way (symbols). While the identified post-conquest signs employ some iconic properties (i.e. the color-based separation of individuals in color banding resembles the real separation of labor tasks between individuals), the primary relationship between the sign-vehicles and the objects they signify is a symbolic one. The relationship between color pattern and aggregation as well as that between knot/ply/attachment direction and markedness could theoretically be reversed given the capacity of all of these devices for complicated logical structuring and cross categorization (Ascher and Ascher 1997:132–133; Ascher 2005:111). However, for the post-conquest khipukamayuqs who produced the identified signs, the color patterns, knot directions, ply directions, and attachment types took on consistent, conventional associations. I expect that Inka khipukamayuqs similarly emphasized symbolic representation, based on their consistent use of the same sign-vehicles as these post-conquest khipukamayuqs—a similarity that is visible in extant archaeological khipus.

However, because symbols are conventional associations by definition, the symbolic mode of representation is difficult to interpret for anyone who does not have inside knowledge about what conventional link is meant to be formed. Without having an Inka khipukamayuq to consult with, I cannot have this inside knowledge at the outset of my investigation. However, in Chapters 3-5, I will utilize identified post-conquest symbolic relationships to empirically test whether or not Inka khipukamayuqs also employed the same symbolic relationships. If the same symbolic relationships were employed by the Inka, I will have re-established the conventional link between Inka khipu sign-vehicles and their objects.

In a second trichotomy, Peirce further argues that a sign-vehicle can be described in itself as a mere quality/possibility (a Qualisign), an actual existent (Sinsign), or a general law (Legisign). Peirce notes that legisigns are usually conventionalized practices established by humans and that they only signify through an instance of their application: a sinsign, or "replica" (1955:103). For instance, when I say the word "book," I replicate an English language convention (a legisign) that correlates the word "book" with the concept for book (Parmentier 1994:8). Likewise, Urton notes that individual instantiations of khipu signs on actual khipus are sinsigns (2003:142). If these khipu signs were conventionalized to any degree, these sinsigns would then be considered replicas of legisigns that governed their use. A convention itself is thus always a legisign and the individual instances of the convention are always sinsigns. Sets of legisigns within a given interpretive community are commonly called "codes" (Jakobson 1971:573–574). In addition to hosting individual legisigns, a code also governs how signs in a sign system can be put together and related to one another using appropriate syntax and grammar (Chandler 2007:147).

For Peircean symbols, a code ensures the consistent production of an intended interpretant from otherwise arbitrary associations between sign-vehicles and objects. Furthermore, codes inform us how symbols are to be related to other symbols. For instance, paired khipu signs designating unmarked and marked categories (e.g. S- and Z-knots) would have been coded as being in binary opposition to one another, and not in opposition with other khipu signs. Note that neither codes nor legisigns need to be widely shared between people in a community; a single individual can utilize a personal convention or a personal code. Peirce's system of signs is ultimately an attempt at philosophical logic and thus will not suffice as the sole terminological base for my investigation into the extent of khipu signification. In order to address whether or not khipu legisigns were widely replicated throughout the Inka empire, I will introduce additional tools to evaluate the production "scale" of legisign replication later in this chapter. For now, however, I focus on the more narrowly defined question of whether or not khipukamayuqs used legisigns and codes.

The identified post-conquest khipu signs seem to have been sinsigns based on legisigns. These legisigns belonged to codes that indicated how the signs were to be used. In these cases, each sign was codified as a member of a binary opposed pair: color banding referred to individual-level data whereas color seriation referred to ayllu-level data, S and Z- knots/ply respectively referred to unmarked and marked categories, and attachment type was shown to similarly signify markedness relations. Demonstrating the codification of color pattern signs, the ayllus in Anchucaya reused their seriated khipus on a year-to-year basis—they continuously replicated the color seriation legisign (Hyland 2016:497). While the same color banded khipus were not used each year, blank khipus were prepared each year by replicating the same color banding legisign (Hyland 2016:497).

In addition, the Mangas khipu board would have been reused on a regular basis throughout the year to publicly record observance of religious obligations (Hyland et al. 2014:2), Each time the khipu board was used, its interpreters would need to actuate the S and Z-knot legisigns and their coded relationship to one another in order to produce the proper interpretants for these signs (i.e. interpret the correct moieties). Furthermore, there is a hint of at least personal coding in the case of the Cutusuma khipu. In Hyland's recounting of the khipukamayuq's testimony she quotes Uhle's field notes as saying "The knots with the males always begin in the middle" (Hyland 2014:4). The notion that gender distinctions were "always" made in this way (even though there is only one khipu under discussion and there is only one male cord grouping on the khipu), seems to indicate that the khipukamayuq used at least a consistent personal code for signifying information via cord order redundancy. In addition, given the consistency in which the khipukamayuq used ply direction to signify unmarked and marked categories for both dairy cows and sheep even within the same khipu, it seems likely that ply was also a part of the Cutusuma khipukamayuq's code. There are hints as well in the Santa Valley khipus that attachment type was used to conventionally signify marked and unmarked categories by the khipukamayuq(s) in the valley. As noted in Chapter 1, the khipukamayuqs seem to have employed attachment type to signify moiety affiliation, whereby one moiety was identified by recto attachment and another by verso attachment (Medrano and Urton 2018). Although the Santa Valley archive is small (six khipus), the fact that this interpretation is supported by the data from multiple khipus suggests that the signs were codified at least to the point that there was some level of consistency across khipus.

We should expect at least a personal level of conventionality for Inka khipukamayuqs as well. Urton, for instance, argues that purely out of practicality, it makes sense for khipukamayuqs to have repeated the same signs they previously used in similar relationships to one another (i.e. for khipukamayuqs to have used a personal code), rather than constructing completely novel symbols every time they wished to signify the same object (2003:33–34). I will make a case for greater amounts of Inka khipu sign conventionalization than personal coding when I discuss the scale of conventionalized sign production later in this chapter, but for now, within a Peircean framework, it should suffice to say that non-numerical Inka khipu signs are also likely to have been coded legisigns that would have been instantiated as sinsign replicas.

Finally, Peirce introduced a third trichotomy to describe the relationship that a sign-vehicle has with its interpretant (1955:103–104). If a sign-vehicle is a sign-vehicle of qualitative possibility for its interpretant, Peirce designated it a rheme. A rheme may be described as a propositional function such as "___ is black," or "___ is a horse" in the sense that the rheme signifies some quality that might be embodied in a possibly existing object (Savan 1988:65). The rheme can be thought of as a predicate, in and of itself, without a defined subject. Thus, in the preceding examples, only the predicates "is black" and "is a horse" are supplied by the rheme. The subject of the predicates must be supplied via another sign. On the other hand, if a sign-vehicle is a sign-vehicle of actual existence for its interpretant, Peirce called it a dicent. A dicent connects sense with reference, such as the proposition "John is a human being," for which both subject and predicate are necessary components (Liszka 1996:41). To round out Peirce's list, a sign-vehicle that is a sign-vehicle of law or convention for its interpretant, like a logical argument, he appropriately called an argument (Liszka 1996:42).

I argue that all of the identified post-conquest khipu signs I have discussed were dicents. For khipukamayuqs in Anchucaya during the 1930s and 40s, the color patterns were symbols of actual ayllu labor measures under their accounting purview. In addition, knot direction, ply direction and attachment type were all used as symbols of socially unmarked and marked categories for their khipukamayuqs. None of these signs were merely rhematic (i.e. only a possible connection with an existing object), but actual recordings of the world the khipukamayuqs lived in and documented, physically connected to that which they refer to (e.g. ply direction is, by definition, affixed to its subject: the cord). Furthermore, none of these post-conquest signs were complex arguments in Peirce's sense (although such arguments could be formed on the basis of multiple dicents within the khipu), but rather propositional recordings of actual facts: that "x is an unmarked category" and "y is a marked category," or that "this khipu records ayllu-level data" and "that khipu records individual-level data."

Thus, under a Peircean framework, the identified post-conquest signs would be called "dicent symbolic legisigns": conventional signs which establish a correlation with their object and provide information about it in a propositional fashion (Peirce 1955:117; Liszka 1996:51). Note that Peirce also calls these signs "dicent symbols," since legisigns are necessarily arbitrary and symbolic. Thus, combining the terms "symbolic" and "legisign" is redundant. As a result, the terms "dicent symbolic legisign" and "dicent symbol" are interchangeable. Notably, this sign type is a complex sign combination of a rhematic symbolic legisign (predicate) and a rhematic indexical legisign (indicating the subject of the predicate) (Liszka 1996:52). For instance, as stated in the example "John is a human being" above, we relate the subject "John" to the predicate "is a human being" (replica of a rhematic symbolic legisign) via a rhematic indexical legisign (i.e. the physical position of the subject "John" in the phrase).

In the example of khipu color banding and seriation, color pattern was partially a symbolic predicate (that signified the possibility of, respectively, individual- or aggregate-level data) and partially a propositional connection (the different color sequences in each color pattern) made to the subject (a cord grouping containing labor contribution data). Thus, color bands within a color banded khipu were propositional connections that indexed groups of cords. The groups of cords indexed by different color bands were the subjects of propositions. Because banding was also partially a symbolic predicate, a khipukamayuq would have interpreted that each cord grouping indexed by a band "records individual labor contribution data." In the same way, a khipukamayuq would have interpreted that each seriated cycle within a color seriated khipu "records ayllu group-level labor contribution data." Furthermore, knot direction, ply direction, and attachment type, were partially symbolic predicates (signifying the possibility of an unmarked or marked category) and partially propositional connections to the knot or the cord they modify (the subject). In this way, a Z-plied cord would have been interpreted as recording a marked category and an S-plied cord would have been interpreted as recording an unmarked category. Likewise, recto and verso attachment type would have indicated that the attached cord recorded either an unmarked or marked category. Similarly, S-knots would have been interpreted as recording values associated with an unmarked category and Z-knots with a marked category.

Following Peirce's insistence that neither symbols nor legisigns manifest themselves in individual instances, each replica of these dicent symbolic legisigns would then be termed a "dicent indexical sinsign" (1955:119). Thus, for example, each time an Anchucaya khipukamayuq replicated color pattern dicent symbolic legisigns, they would have interpreted color bands as referring to individual-level data, and the different colors of a color seriated sequence as referring to group-level data.

This dicent symbolic legisign designation seems consistent with what khipu scholars have often hypothesized for non-numerical Inka khipu signs and lumped under the blanket term for non-phonetic signs: "semasiographic." For instance, note the similarities between Frank Salomon's notion of khipus as complex infographics composed of sets of predicates and Peirce's dicent symbolic legisigns that are composed of symbolic predicates and propositional connections to a subject. However, the preceding discussion expands beyond simply labeling khipu signs as semasiographic. Instead, I have clarified exactly how identified post-conquest khipu signs would have worked as signs and I have provided a conceptual vocabulary for empirically investigating whether or not the same dicent symbolic legisigns were also replicated by Inka khipukamayuqs. Such empirical investigation, which I will pursue in Chapters 3-5, will get us even closer to understanding the types of signs Inka khipukamayuqs used to signify information.

In summary, the identified post-conquest khipu signs were dicent symbolic legisigns that utilized codes pairing S- and Z-knots, S- and Z-plied cords, Recto and Verso cord attachments, as well as color seriation and color banding in binary opposition to one another as unmarked/marked pairs. In addition, I have made the argument that Inka khipu signs were also legisigns within codes that contained rules of binary opposition. Furthermore, I argued that dicent symbols would have likely been at least one means of signifying non-numerical information that is consistent with what scholars have argued khipu signs should be capable of signifying. However, good reasons and arguments are not necessarily empirical reality. The question now becomes: were such dicent symbolic legisigns actually replicated by Inka khipukamayuqs? Have we identified a type of sign that Inka khipukamayuqs used to signify non-numerical information? If so, what does this say about Inka khipu semiosis more generally? These questions form the basis of the first fundamental question I seek to answer in this dissertation: what type of signs did Inka khipukamayuqs produce?

2.2 From Studying Individual Khipus to Exploring Sign Patterns Across Many Khipus

So how does one answer the question of whether the Inka replicated the same legisigns identified in post-conquest times and whether marked/unmarked pairs of dicent symbolic legisigns were employed as Inka khipu signs? In Chapters 3-5, I will test whether or not the types of signs that were identified in post-conquest times were used in extant archaeological Inka khipus as well. Assessing legisign replication, however, means stepping beyond the close study of individual khipus and instead looking at aggregate patterns of khipu signs for evidence that marked/unmarked legisigns were replicated and not just used in isolated instances. Thus, I will search for patterned sign-use within the Harvard Khipu Database—a resource that features 973 catalogued extant archaeological khipus from collections around the world and detailed descriptions of 626 of those khipus, as of the time of my analyses. The recorded khipus are Inka-style khipus of the type shown in Figure 1.2 (Chapter 1) and do not include khipus from divergent cord-keeping traditions like the post-conquest khipus studied by Hyland. The Harvard Khipu Database is thus an ideal resource for identifying general sign patterns in specifically Inka khipus. The Harvard Khipu Database Project, which began in 2002 under the direction of Khipu Database manager Carrie J. Brezine, stores khipu descriptions in a MySQL relational database (KDB, for Khipu Database). This data structure makes it easy to query both khipu-level data such as provenance and cord-level data such as color, numerical value, ply direction, knot direction, and attachment type.

However, I should note that the khipus in the database are not a complete geographic sample of active khipus during the height of the Inka empire. Much of this sampling bias has to do with khipu taphonomy: khipus do not preserve well in the Andean highlands where it is too rainy and moist for the preservation of fabrics. In fact, only one collection (of 32 khipus from Laguna de los Cóndores, in northern Peru) comes from the highlands, while the vast majority come from the Pacific coastal deserts in Peru and Northern Chile (Urton 2015:151). Unfortunately, this means that we cannot study and attribute khipus from the heart of the Inka empire (for instance, from the Inka capital of Cuzco), where khipus likely would have been stored in central archives. As such, there will always be cause for some uncertainty in any conclusions we reach about overall recording patterns across the Inka empire. While this is certainly a source of sampling bias when analyzing a fiber-based artifact, the coastal regions yield khipus across an enormous area from North to South (approximately 1500 km from Laguna de los Cóndores all the way down through Arica, Chile). On the basis of the large number of Inka-style khipus in the database and this vast geographic scope, I proceed under the assumption that the KDB's collection of khipu data is representative of the total corpus of khipus active during the time of the Inka empire.

2.3 Identifying the Production of Inka Khipu Signs

How will I test whether the Inka khipus recorded in the KDB replicated the same legisigns identified in post-conquest times? Note that I am not just looking for evidence of a single material feature in the extant khipus (e.g. evidence that knots were tied in different directions). I could directly search for such a material khipu feature in the KDB without further theoretical discussion. To the contrary, I am looking for evidence of specific triadic signs; the material aspect of a khipu sign is only the sign-vehicle component of a complete triadic sign. Therefore, it is also imperative that I address how I will determine whether or not extant Inka khipu signs had the same interpretants and referred to their objects in the same way as the identified post-conquest signs. To get to this point, I consider in this section the production of Inka khipu signs—the process by which Inka khipukamayuqs brought objects, sign-vehicles, and interpretants into contact with one another through codes and the medium of cords and knots. By explicitly considering the process by which khipu signs would have been produced, I am able to develop the empirical tests I use in Chapters 3-5 for assessing whether or not the extant archaeological khipus of the KDB employed dicent symbolic legisigns in the same way that the post-conquest khipus discussed in this chapter employed such legisigns.

Let us consider how the sign production process works and what implications this process has for identifying dicent symbolic legisigns in extant archaeological khipus. Umberto Eco developed a typology that I find helpful for considering how signs with material sign-vehicles, like khipu signs, are produced (Eco 1976). Specifically, he classifies "modes of sign production" by 4 parameters (Eco 1976:217). For each sign, there is first the physical and interpretive labor required to produce a given expression.

Up to this point, we know very little about the physical labor involved in the production of Inka khipu sign-vehicles, other than that which we can infer from their end products in the KDB. In the absence of data from a khipu production context, for instance, Conklin inferred a likely production sequence based on his careful analysis of completed khipus (2002). First, khipu makers needed to procure material to make khipu cords. Cotton fiber, with its great variety of natural colors in Peru, was the most commonly-used material for producing khipu cords (Conklin 2002:60). Cotton was also occasionally dyed to produce colors outside the natural range, such as blue. A smaller group of khipu cords were made using alpaca fiber for cords, which could be dyed in brighter colors than cotton (Conklin 2002:61). Even fewer khipu cords were made with alternative fibers such as bast fiber and human hair.

Once this raw fiber was procured, it was spun and then doubled over and plied into khipu cords. Conklin notes that the primary cord would have needed to be produced before all others because pendant cords, top cords, and subsidiary cords were either directly or indirectly attached to it (2002:66). As pendant and top cords were attached to the primary cord, further subsidiary cords could be added to these cords. This part of the production process has not previously been documented archaeologically, leaving it unclear whether cords, with their unique colors and color combinations, were made on-site, as they were needed by khipukamayuqs, or were pre-made elsewhere. However, in 2016, in my excavations at Inkawasi, we identified cord production contexts immediately adjacent to khipus that suggest that at least some of the khipu cords were made on-site, as they were needed by the khipukamayuqs. We will return to this discussion of khipu cord production at Inkawasi in Chapter 4, where I describe our findings in greater depth and their relation to the production of cord color signs. Finally, knots could theoretically be tied onto a cord either before or after a cord was attached to the khipu. Thus, knot-tying could have occurred much later in the production process than primary and pendant cord production.

In terms of Eco's first parameter of sign production, the labor involved in the physical production of a khipu sign-vehicle described above could involve anything from the replication of an existing sign convention, to the invention of a new sign. If the Inka replicated the same legisigns identified in post-conquest times, however, I would expect to observe multiple instances of their sign-vehicles in the KDB. Furthermore, each one of these replications should involve the same overall sign relationship, producing the same interpretants each time and the same relationship between sign-vehicle and object.

According to Eco's second parameter of sign production, a sign is produced with a varying number of tokens for a given type (what Eco and others call the type/token ratio). Types are equivalent to Peircean legisigns and tokens are individual instantiations, or sinsign replicas of legisigns (Savan 1988:22). As an illustration, by writing this chapter using the 26-character English alphabet, I am drawing on only 26 conventionalized characters (types) to produce tens of thousands of written letters (tokens). Low type/token ratios thus tend to occur when tokens are produced according to a pre-existing expression type. In the case of the English alphabet, for example, the ratio of types (26) to tokens (tens of thousands) is very small. High type/token ratios tend to occur on the contrary when expressions are directly accorded to content; either because the expression type does not exist yet, or the expression type is identical with the content type (Eco 1976:183–184). For instance, a painter using novel techniques purposefully breaks from past conventions and produces a painting with new ideas and style. Such a work would be unique to the painter—a type (or series of types) without many (if any) other tokens, and thus a work with a high type/token ratio.

I expect Inka khipukamayuqs to have produced replicas of the identified dicent symbolic legisigns according to low type/token ratios if the signs were highly conventionalized (as in the example of the English alphabet). Higher type/token ratios would indicate that the khipukamayuqs replicated legisigns in a less conventionalized way—perhaps only at certain times or purely out of coincidence. Practically, in order to recognize replicated legisigns in the KDB, I require a low enough type/token ratio that I can identify the statistical signal of a particular legisign's replication. For instance, if color banding was used to signify individual-level data on only a few khipus in the KDB, I would not be able to identify a statistical effect large enough to argue that these were replicas of the same legisign, or even that there was a central color banding legisign at all. Thus, I require a low enough type/token ratio that will allow me to interpret whether or not Inka khipukamayuqs replicated the same types of dicent symbolic legisigns as their post-conquest counterparts.

The third parameter is the kind of continuum to be shaped by the given sign expression: homomaterial (i.e. made out of the same material stuff as what is being represented), or heteromaterial (different material expressions). A sign that shapes a homomaterial continuum, for instance, could be a sample of that which it represents–for instance, a test tube of water that signifies the ocean from which it was drawn. A sign that shapes a heteromaterial continuum, on the other hand, could be an illustration of a wave on a piece of paper that also represents the ocean (but through a different material expression). Here, we know that khipu signs represent entities that are different from knots and cords themselves, so I expect to see instances of khipu sign expression shaping a heteromaterial continuum (i.e. referring to objects from the Inka cultural universe beyond the material stuff of the knots and cords themselves).

Finally, Eco focuses on the mode of articulation: everything from systems with precise combinational units that are highly coded (such as the grammatical rules for combining words in the English language), to those in which possible compositional units are undercoded (Eco uses the example of an artwork, where components can be freely and creatively combined according to the whims of the artist; Eco 1976:188). I expect to see evidence that Inka khipukamayuqs produced highly coded signs, meaning they had strict rules for using and combining signs. For instance, the identified post-conquest khipu signs were produced according to highly developed codes, where S-knots/plied cords were always unmarked and Z-knots/plied cords were always marked. If Inka khipukamayuqs used the same codes as their post-conquest counterparts, then we would expect them to also have used dicent symbolic legisigns according to similar rules of binary opposition.

Therefore, in summary, if Inka khipukamayuqs replicated the same legisigns identified in post-conquest times, I would expect the Inka khipu sign production process to have followed Eco's mode of replicating combinational units along an arbitrary heteromaterial continuum by a pre-established, highly developed code. In order to identify such replication in the KDB, however, I require a low enough type/token ratio that will allow me to separate the signal of a particular sign usage from the noise of divergent sign usages. Legisigns cannot signify without being replicated. If Inka khipukamayuqs replicated the same legisigns identified in post-conquest times, I would thus expect to observe the same khipu sign relation, produced in the same knot and cord form, replicated a large enough number of times to be statistically visible (i.e. a low type/token ratio). Furthermore, I would expect the Inka khipukamayuqs to have referenced an existing code, indicating the proper rules of binary opposition for their legisigns. In the case of ply direction, for instance, I would expect Inka S-plied cords to have stood for unmarked categories and Z-plied cords to have stood for marked categories, as well as for this relationship to have been replicated.

Up to this point, there has never been any empirical evidence for the replication mode of khipu sign production described above. There have, however, been promising hints of sign replication and low type/token ratios. For instance, Urton found patterned regularities in knot directionality across 99 extant khipu in the Museum für Völkerkunde in Berlin (1994:285–287). One of his most salient findings in light of Hyland's work on knot direction is that the most common knot combination was the one in which all knot types in a khipu (single, long, and figure-eight) were tied as Z-knots and the least common was one in which all knot types were tied as S-knots (1994:285). This patterned regularity is the opposite of what would be predicted if S-knots signified unmarked categories and Z-knots signified marked categories, as Hyland et al. suggest (Hyland et al. 2014). Furthermore, Urton has noted the striking homogeneity in the overall structure of Inka khipus (the specifics of which are shown in Figure 1.2 in Chapter 1), arguing that only with some level of conventionalization would such homogeneity be likely (1994:294). While tantalizing, however, these regularities do not in themselves imply sign replication with a low type/token ratio. These findings are uniformities in the material aspect of knot direction signs. Urton's analysis does not take into account whether the relationship between the material sign-vehicle and the interpretant was also replicated, or if there was replication of the way in which the sign-vehicle stood for its object. This means that, for different Inka khipukamayuqs, the same knot direction sign-vehicle might very well have stood for completely different things. Furthermore, the study does not address whether knot direction signs were highly coded as being in binary opposition with one another, or if there were weakly coded relations between the two that were not consistently enforced. Analyzing the material aspect of a sign alone tells us very little about whether or not a legisign was replicated; we must consider how the full set of relationships that made up a khipu sign were produced.

However, because there are not direct transcriptions (i.e. colonial-era renderings of khipus in written texts) of all extant khipus, we do not have access to the original interpretants involved in each sign. How do we move beyond just the material aspect of the sign and assess whether or not the whole sign was replicated by Inka khipukamayuqs at a low type/token ratio, in a highly coded fashion? Signs are always part of a larger world of signs; they are never completely isolated from the cultural world in which they were produced. Thus, I draw on intertextual relations with better understood Andean semiotic media to build theories for how Inka khipu signs worked (see discussion of such intertextuality in Brokaw 2010). Theories about how a particular sign worked can then be quantitatively tested against the large body of evidence contained in the KDB. For instance, I draw on scholarship about the structure and poetics of the Quechua language, as well as the relationships between khipu semiosis and Andean weaving traditions to build hypotheses with testable quantitative outcomes. I then employ already deciphered numerical khipu signs to test these quantitative hypotheses about the non-numerical signs, assessing whether or not the khipus contain the expected quantitative outcomes derived from a particular hypothesis.

Consider color pattern signs, for example (see full analysis in Chapter 5). Remember that each dicent symbolic legisign is composed of a rhematic symbolic legisign (predicate) and a rhematic indexical legisign (indicating the subject of the predicate). Thus, based on Hyland's study of post-conquest color patterns, we should expect color banding in extant khipus to have partially been the predicate "___ records individual-level data" and color seriation to have partially been the predicate "___ records group-level data." Thus, I must assess whether or not the link to the dicent's subject correctly points to my expectations for these predicates. Does the link to the dicent's subject match my expectations of individual-level data for banded khipus and group-level data for seriated khipus? The subjects here are the cord groupings that are indexed by the color bands themselves, which I expect to contain individual-level numerical data consistent with Hyland's findings for banded khipus in Anchucaya (see further discussion of what such individual-level numerical data should look like in Chapter 5). The same would then also be true for seriated khipus. The subjects on seriated khipus would be the cord groups indexed by each seriated sequence of colors, which I would expect to record numbers consistent with group-level numerical data consistent with Hyland's findings for seriated khipus (see further discussion of what such group-level numerical data should look like in Chapter 5). While these numbers are not themselves a part of the color pattern signs, they can be used as clues to determine what the signs might have meant. Therefore, in summary, if the Inka replicated the same legisigns identified in post-conquest times, I would expect to find a systematic relationship between color pattern and the order of cord value magnitude in recorded khipus in the KDB (i.e. lower cord values indicative of individual-level data and higher cord values indicative of aggregate-level data).

To assess whether a pair of signs existed in a marked/unmarked relationship with one another when there are no other available contextual indicators, I rely on the relative frequency at which the signs occur. Recall that unmarked signs are said to be inclusive of marked signs. For instance, "day, " an unmarked term, can be used in the English language in an inclusive sense to refer to both day and night together (in the sense of a 24-hour day), whereas "night," a marked term, can only be used in a restricted context to refer to nighttime hours. Therefore, because they are more inclusive signs, we might expect unmarked signs to occur more frequently than marked signs. For this reason, I follow Urton in suggesting that, for any given pair of khipu signs, the sign that occurs the more frequently in the KDB is likely to be unmarked, whereas a sign that occurs less frequently in the KDB is likely to be marked (Urton 2003:145).

2.4 Investigating the Scale of Inka Khipu Sign Production

While up to this point no one has empirically demonstrated large-scale conventionalized Inka khipu sign production, khipu scholars have provided indirect evidence that Inka khipukamayuqs produced widely conventionalized signs. For instance, at least some khipukamayuqs received prestigious Inka burials featuring imported Inka pottery and wooden drinking cups (Ascher and Ascher 1997:63–64, citing unpublished notes from Uhle's excavations in Ica). Marcia and Robert Ascher suggest that these Inka-centric burials are evidence that khipukamayuqs participated in a centralized Inka state institution, as bureaucrats who both recorded and administered state resources. It would seem that an organization as complex as the Inka bureaucracy would have necessitated some form of conventional khipu sign communication to link individuals in different authority positions (see Urton 1994:294). Furthermore, if we define bureaucracy as an institution in the Weberian, rationalized and impersonal sense, it seems likely that the Inka bureaucracy would have employed widely conventionalized khipu signs that allowed information to function outside of the idiosyncrasies of any given khipukamayuq's code (Weber 1968[1922]:62). Supporting this assertion, the chronicler Murúa tells us that Inka khipukamayuqs learned their craft in a four-year program in Cuzco, with two full years devoted to the interpretation and production of khipu signs (2001[1590]:364). Presumably, this training allowed khipukamayuqs to produce signs that other centrally-trained khipukamayuqs could correctly interpret. Conklin, for instance, cites a Guaman Poma illustration (Figure 2.1) equating khipus with "letters" and numerous examples of rolled up extant archaeological khipus as evidence that there must have been some shared set of meanings that allowed distant khipukamayuqs to send and interpret each other's records (2002:55).

In this sense, we might argue that Inka khipukamayuqs were highly skilled, "attached" specialists in the sense that they did not control the products of their own labor (following the reformulation of the term "attachment" by Clark 1995 and Flad 2007:111 from the conception of Costin 1991). Rather, khipukamayuqs produced signs that were meant for state use and designed for high mobility throughout the empire. Therefore, given the necessity of information-transfer in the Inka bureaucracy and documentation of centralized khipukamayuq training, it seems more than likely that khipu signs were widely conventionalized—at least at some levels of administrative hierarchy.

Figure 2.1: *Illustration of a Khipu Used as a "Letter" (Guaman Poma de Ayala 1980[1615]:178)*

While these are solid arguments in favor of widespread conventionalized sign production, we still do not have clear empirical support from khipus themselves of large-scale conventionalization. Hinting at such scale, however, Urton found in his 1994 study of extant khipus in the Museum für Völkerkunde in Berlin that his identified S- and Z-knot patterns were spatially widespread throughout the Inka Empire (1994:287). In addition, Urton argues that only with widespread, shared conventions could there be such homogeneity in the overall structure of khipus throughout the Inka Empire (1994:294). However, as I discussed previously in this chapter, Urton focuses on the material, sign-vehicle aspect of these signs and does not consider the relationship of the sign-vehicle with its interpretant or object. As such, the patterns Urton finds are not enough evidence on their own to suggest that the same signs were being used widely throughout the empire.

Quilter, to the contrary, has argued that despite the complexity of information signified by khipukamayuqs, there is no necessary reason to think that Inka khipukamayuqs used the same conventionalized signs throughout the empire (2002:220). Rather, an alternative model of khipu conventionalization might predict a patchwork of knot traditions. For instance, regions that did not have pre-existing knot traditions may have employed strongly centralized Inka approaches to khipu production and regions that did have existing traditions may have utilized their traditional methods of sign production (Quilter 2002:203). This line of thought opens a range of empirical questions about the scale of conventionalized Inka khipu sign production. Did different regions utilize different khipu sign production techniques? Or did the Inka impose sign production techniques on all regions universally? Furthermore, did only certain levels of Inka administrative hierarchy employ conventionalized signs? Perhaps only certain specialists within the administrative hierarchy received the four-year centralized training that Murúa described. Local-level khipukamayuqs may have used idiosyncratic ways of signifying (that then needed to be translated into the signs of higher bureaucratic levels). In contrast, higher bureaucratic levels may have then required more standardization for checking and cross-checking information across the empire. Furthermore, khipukamayuqs might have signified using different signs depending on the genres they produced signs within. Brokaw, for instance, argues that one of the reasons Inka khipu decipherment has been so difficult is that researchers often expect khipu signs to have functioned like alphabetic script, where multiple genres can be represented by the same signs (2010:271). However, Inka khipus may instead have had genre-specific conventions that make it impossible to completely match signs between genres as divergent as herding khipus and calendrical khipus.

Archaeologists studying other forms of specialized production typically define "scale" as the number of individuals working in a production unit as well as the principles of labor recruitment (Costin 1991:15). For the purposes of answering how widely conventionalized Inka khipu signs were produced, I specifically focus on the first part of this definition: the size of the labor force working in a production unit—that is, the size of the khipukamayuq labor force producing a particular sign. The raw quantity of identified signs is not sufficient to estimate the size of the khipukamayuq labor force producing them because extant khipus form only a small fraction of the total number of Inka khipus once in operation. I argue, however, for the legisigns I am studying, that the relative size of a sign production unit can be evaluated by assessing the dominance of the codes that these legisigns belonged to. Jakobson notes that even within a linguistic code, innumerable sub-codes act to make up the more general, language-level code for a community of interpreters (1971:574). For instance, when we speak in English, we generate interpretants (i.e. correlations between sign-vehicles and objects) through our regional, class, and race sub-codes. Together, all of these fragmented codes ultimately form a master "English" code. The same could be true for any sort of coded semiotic practices, even those that are not strictly linguistic processes.

However, Stuart Hall points out that the use of such sub-codes always involves a process of political negotiation, with non-dominant codes challenging the ways in which dominant codes instruct us to produce and interpret signs (Hall 1980:58). Thus, evaluating the relative size of the khipukamayuq labor force that replicated legisigns is fundamentally a question of how dominant khipu codes were within the Inka khipu semiotic medium. For instance, in order for me to identify that color banding and seriation were used as signs in the KDB khipus demands that they belonged to a code of some dominance. Otherwise, these signs would not have been used enough for me to statistically model their relationship. The remaining fundamental question of this dissertation, though, is whether this color pattern code and the codes for knot, ply, and attachment type were only dominant in pockets of the Inka khipu medium, or were pervasive throughout. Were khipukamayuqs only referencing a dominant code in certain contexts and not in others? In certain regions, but not in others? To answer these questions, I argue we must consider multiple axes of scalar variation. In Chapters 3-5, I assess the dominance of identified codes along two main axes: the geographic scope of the codes' signs and the different khipu genres that featured the signs.

First, I will assess the geographic scope of code use. Specifically, I will assess whether khipukamayuqs replicated the same legisigns identified in post-conquest times widely across geographic space, based on extant khipu provenances. Note that while many of the KDB khipus have inexact provenances, the region where they were found is often recorded and can be used to identify coarse-grained spatial effects. If I find that the signs were spatially widespread across the former Inka Empire, then they would not likely be the result of only a single, localized individual or group. If instead I only identify small regions that produce the same signs, then I would interpret the identified signs as localized production practices that will need to be analyzed in their own right. I would estimate a spatially-circumscribed sign production practice of this sort to have had a smaller khipukamayuq labor force than a spatially-widespread sign production practice.

Recall from Chapter 1 that different parts of the empire were conquered by the Inka at different times and often administered in radically different ways depending on the local environmental, political, and economic context (Covey 2000:120). Therefore, it would not be surprising for there to have been certain pockets of the empire that used alternative sign production practices, with divergent codes from the rest of the Inka empire. As such, khipu sign production practices could tie into larger questions of Inka political geography–by which I mean, the investigation of the spatially uneven effects of Inka political practices. For instance, if only certain geographic pockets of the empire used alternative sign production practices, this could indicate subversion of the hegemonic codes of the Inka state, or unique power dynamics that only existed in these locales and, thus, allowed for the proliferation of different semiotic codes. However, it remains an empirical question whether or not the varying Inka regional administrative and political strategies had any effect on the signs being used in different parts of the Inka empire. In the remainder of this dissertation I will begin to address this question as I identify how the signs I am studying were used across the Inka empire—whether through wide replication of a central code, or an uneven patchwork of local and personal codes.

However, while signs might be conventionalized over a wide geographic area, without analyzing their specific uses in terms of genre (i.e. labor khipus vs. storehouse accounting khipus, etc.), it is difficult to identify the true scale of conventionalized sign production. For instance, if a legisign was replicated throughout the Inka empire, but only used within a single genre, this sign should be considered to have been smaller-scale production than a sign that was also replicated throughout the Inka Empire, but used in multiple genres. I make use of khipu excavation context and ethnohistorical corollaries to evaluate the genre of khipus in the KDB and assess whether or not different genres utilized different codes.

The specific excavation context I make the most use of is that of Inkawasi, on the southern coast of Peru in the Cañete Valley. In the 2013-2014 field season at the site of Inkawasi, Peruvian archaeologist Dr. Alejandro Chu excavated 34 khipus in situ on the floor of an Inka storehouse. The khipus were found beneath rock wall tumble and covered by the foodstuffs (that they presumably recorded) on the floor of the storehouse (Urton and Chu 2015). The Spanish Chronicler Cieza de León tells us that the storehouses at Inkawasi supplied Inka military forces under the Inka ruler Thupa Yupanki in their four-year war against the native Huarco in the early 16th century, before the Spanish Conquest (see Hyslop 1985:8–13 for a summary of the account). After the Inka had beaten the Huarco in battle, the Inka are said to have razed and abandoned Inkawasi (Hyslop 1985:13)—presumably knocking down walls over the khipus excavated in 2014.

In 2016, I supplemented my more general, comparative study of the full corpus of khipus recorded in the KDB with further excavation at Inkawasi (see results in Chapters 3 and 4). My own excavation of khipus in addition to further analyses of khipus already recovered from the site, allowed me to assess the degree to which the signs I investigate (knot direction, cord color, and color pattern) were replicated within the storehouse accounting genre and compare this replication to khipus from other genres in the KDB.

For a storehouse as far away from Cuzco as Inkawasi, Urton and Chu argue that there must have been a degree of widespread administrative conventionality for khipukamayuqs to have been able to communicate the accounting operations at the storehouse facility to the centralized administration in Cuzco (2015:515). So, at Inkawasi, I would expect khipu signs to have been replicas of widespread geographic legisigns that were common across the storehouse accounting genre, if not across all khipus in the KDB. However, this conventionality has not been empirically demonstrated.

In summary, for the remainder of this dissertation, I will empirically assess extant Inka khipus in the KDB for evidence that non-numerical Inka khipu signs were produced as marked/unmarked pairings of dicent symbolic legisigns. Furthermore, I will assess the scale at which these signs would have been produced. I will analyze the scale of khipu sign production along two axes: Geographic Scope and Genre. By considering these two axes, it is possible to address the relative size of the labor force across the Empire producing any given type of sign, whether only within a specific genre, or in multiple genres. Specifically, I investigate these questions through the lens of three signs: knot direction, cord color, and khipu-level color patterns.

Chapter 3

Inka Khipu Knot Direction and the Signification of Numeration

3.1 Introduction

As I analyzed the khipus in the KDB across a number of different variables, I found a unique markedness relationship that occurred again and again between khipu knot direction signs: single knots were predominantly tied in the Z-knot direction while figure-eight and long knots were more often tied in the S-knot direction. I argue this pattern occurs because khipukamayuqs used knot direction to signify the grammatical relationship between a higher decimal number and a lower one, reflecting qualities of Quechua numeration, where higher decimal places are said to "possess" (be unmarked in relation to) lower decimal places (the marked categories in the relationship). Thus, knot direction might be said to have been used as a grammatical marker in signifying numbers, a dicent symbol that directly posits a marked/unmarked status for each knot according to its numerical status in Quechua. Over the course of this chapter, I systematically evaluate this hypothesis.

I begin this chapter with my analysis of the storehouse accounting khipu archive at Inkawasi, where I excavated additional khipus in 2016. I then expand the analysis to demonstrate that my findings similarly apply across additional administrative khipu archives at Pachacamac and Puruchuco. Finally, I demonstrate that my findings apply as well at an aggregate level across the rest of the khipus in the KDB that contain data on knot direction.

3.2 Background

Recall from Chapter 1 that single knots, long knots, and figure-eight knots can all be tied with a diagonal axis across the body of the knot that runs either from the top left to lower right, so that the knot diagonal axis direction looks like the central line "\" in an "S," or from the top right to lower left, so that the knot diagonal axis direction looks like the central line "/" in a "Z" (see Figure 1.6 in Chapter 1). Thus, there are two possible knot directions for every knot tied on a khipu: S or Z.

For Inka khipus in the KDB, Urton has theorized that Z-knots signified unmarked categories, whereas S-knots signified marked categories based on the frequency with which both these categories occur (2003: 153; also see Chapter 1 for a fuller explication of this argument). As I described in Chapter 1, Hyland found post-conquest empirical evidence to support Urton's theory that knot direction signified marked and unmarked categories. Specifically, she studied a 19th century "khipu board" in the village of Mangas (Ancash Department) and found that knot direction was used to signify moiety distinctions in post-conquest times (Hyland et al. 2014:196). However, in contrast to Urton's theory for Inka khipus, Z-knots were used to signify the lower moiety (marked) and S-knots were used to signify the upper moiety (unmarked).

The Mangas khipu board provides valuable evidence that knot direction was used up to recent times by khipukamayuqs to designate pairs of marked and unmarked social identities. Furthermore, in terms of the process of khipu semiosis, each knot acted as a propositional statement about the individual to whom the knot belonged—"he belongs to the upper moiety" or "she belongs to the lower moiety." Recall from Chapter 2 that these types of symbolic propositional connections are called dicent symbols in Peircean language. Thus, any knot direction signs that signified marked and unmarked categories acted as dicent symbols/predicates for the knot that they modified.

For the remainder of this chapter, I assess whether Inka khipus used S- and Z-knots to designate marked/unmarked pairs and, by extension, whether the khipus utilized dicent symbols to convey non-numerical information. If knot direction was used to signify marked/unmarked categories, I additionally assess whether Inka S-knots were used to signify the marked (consistent with Urton's hypothesis) or unmarked category (consistent with the post-conquest findings of Hyland et al.).

3.3 Knot Direction at Inkawasi and Beyond

In 2016, I had the good fortune of excavating at the site of Inkawasi. In the 2013-2014 field season at the site, Peruvian archaeologist Dr. Alejandro Chu excavated 34 khipus in situ on the floor of an Inka storehouse. Inkawasi sits on the Southern Coast of Peru in the Cañete Valley (see Figure 3.1) and its khipus in particular give us a unique view into Inka administrative activities that would have taken place at the facility and its immediate environs.

Figure 3.1: *Map of Peru with Inkawasi Starred*

The 2013-2014 khipus were found beneath rock wall tumble and covered by foodstuffs (that the khipus presumably recorded) on the floor of the storehouse (Urton and Chu 2015; found in Sector A of Figure 3.2).

As I mentioned in Chapter 2, the Spanish Chronicler Cieza de León tells us that the

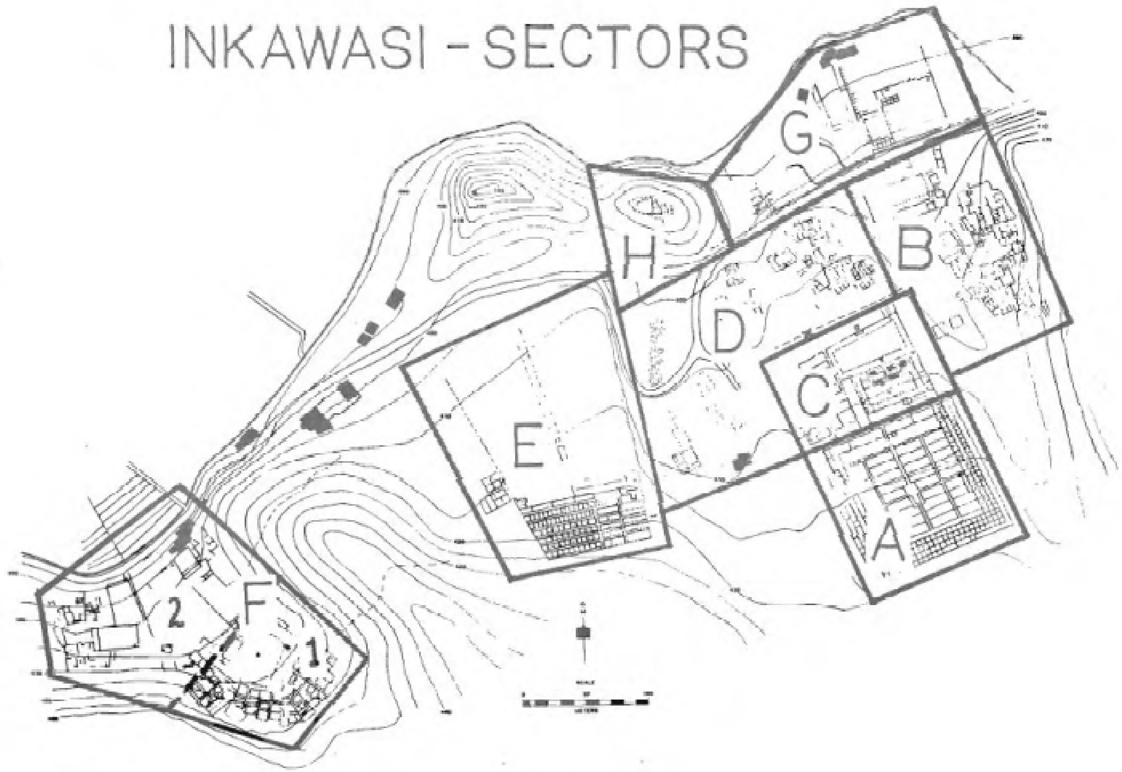


Figure 3.2: *Map of Inkawasi (Hyslop 1985:15)*

storehouses at Inkawasi supplied Inka military forces under the Inka ruler Thupa Yupanki in their four-year war against the native Huarco in the early 16th century, before the Spanish Conquest (see Hyslop 1985:8–13). Settlement survey of the Cañete Valley shows Inkawasi to have been at the top of the settlement hierarchy, with numerous other smaller Inka storehouse sites in the valley that may have reported to it (Marcone and Areche 2015:59). After the Inka had beaten the Huarco in battle, the Inka are said to have razed and abandoned Inkawasi (Hyslop 1985:13)—presumably knocking down walls over the khipus excavated in 2014.

In 2016, we moved excavations to Sector B (see Figure 3.2), considered by Hyslop to be the "king's palace" (for when the Inka ruler came to inspect the military garrison) based on his survey of the ceramics and architectural features at the site (Hyslop 1985:17-19). Despite the title of "palace," much of the remaining Inka architecture associated with the sector consists of further *collcas* ("storehouses"), incorporated into later architecture. Within several of these collcas (highlighted in Figure 3.3), however, we found additional khipus (23 in total, which I added to the KDB), along with the raw materials and semiotic tools khipukamayuqs would have used to produce the khipu cords and color signs (discussed further in Chapter 4), albeit empty of the foodstuff deposits found in Sector A. Whereas the Sector A khipus seem to have been directly involved in the day-to-day recording of Inka foodstuffs stored at the site, Sector B khipus were commonly found tightly bound and buried with large numbers recorded on them, suggesting that they may have been archival khipus that kept some sort of summary statistics for overseers at the site (Clindaniel et al. 2019).

Figure 3.3: *Inkawasi Sector B Collcas with Khipu Find Sites Highlighted in Yellow*

In order to test for evidence of conventionalized knot direction signs, I started by performing a series of statistical tests on all of the recorded khipus from Inkawasi (n=52; not all of the 57 excavated khipus were in good enough condition to be analyzed and added to the KDB). All of the 52 khipus in the Inkawasi archive were analyzed either by Gary Urton (UR255-280) or myself (JC001-023) and we recorded knot direction data for every knot on the 5,708 analyzed cords.

Specifically, I tested knot direction in terms of knot type (figure-eight, long, and single knots), knowing that the two knot directions are found on all three knot types and that each knot type explicitly relates to one another in a (physically) hierarchical fashion on a khipu cord. Recall that, in terms of physical hierarchy, long and figure-eight knots occur at the bottom of cords (in the units position), whereas single knots occur at the higher decimal levels of cords. Based on this physical hierarchy and the convenience of the built-in relation to knot direction, I hypothesized that knot types might relate to one another in a marked/unmarked fashion, and that, if knot directions were used as marked/unmarked signs, they would have been a prime way of signifying this knot type distinction.

While the numerical value of each knot could also have been designated marked or unmarked via knot direction, I could not formulate a clear way of testing their relationship to knot direction without *a priori* knowledge of which numerical values recorded marked values and which ones recorded unmarked values. Without being able to distinguish marked from unmarked numerical values, it would be impossible to assess whether knot direction signs relate to one another in a markedness relationship. Thus, in the absence of any other possible marked/unmarked pair, I focused on whether the physical hierarchy of the knot type signs was signified by marked and unmarked sign vehicles (i.e., knot direction). For instance, do single knots that are tied higher on a cord (i.e. in decimal positions in the 10's, 100's, etc.) occur in one knot direction while long and figure-eight knots (i.e. in the units position) lower down on the same cord display the other direction? If the physical hierarchy separating knots on cords is reinforced by a distinction in knot direction, I argue this is evidence that knot direction was used to signify relationships of hierarchical binary opposition (e.g., unmarked vs. marked) in the Inkawasi khipus.

To analyze the data, I used the Python Data Analysis Library (Pandas, version 0.18.0) in Python 2.7 (McKinney 2010; see Appendix A.1 for code). I wrote all my dissertation code in Python 2.7 due to its combined ability to perform high-level statistical programming and its highly readable code. Furthermore, I wrote the code in a fully reproducible Jupyter notebook to promote replication by other researchers and to provide detailed information about my assumptions and methodology.

For this chapter, I first wrote a series of Python functions to count the number of S- and Z-knots for each knot type, both within and between the individual Inkawasi khipus, parsing each one by cord, knot, khipu, and so on. These counts enabled me to test for statistically significant numbers of S- and Z-knots using statistical tests from Python's Scientific Computing library, SciPy, version 0.18.0 (Jones et al. 2001). I did not distinguish the type of cord each knot was tied onto. Thus, knots that were tied to pendant cords, top cords, and subsidiary cords were all included in the analysis.

Note in Figure 3.4 that the mean counts of S- and Z-knots overlap considerably for long and figure-eight knots within a given khipu. The mean counts of S- and Z-knots for each of these knot types are remarkably similar and their 95% confidence intervals overlap considerably (the lines in the plot represent 95% confidence intervals). However, for single knots, there is a statistically significant difference between the use of S- and Z- knots. The 95% confidence intervals diverge widely, meaning single knots only rarely were tied in the S-direction.

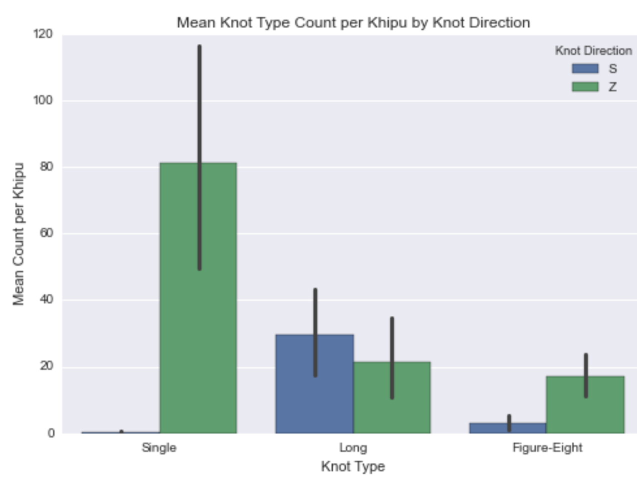


Figure 3.4: *Mean Knot Type Count per Khipu by Knot Direction (with 95% confidence interval lines produced by bootstrapping)*

Figure 3.4 also suggests a systematic use of the Z-knot direction for single knots, but a more fluid use of both S- and Z-knots for the long and figure-eight knot types. These lower hierarchy knots are tied as S- and Z- knots at roughly an equal rate to one another (especially long knots), according to Figure 3.4—a much higher rate of S-knot use than is seen with the single knots.

Recall that marked and unmarked signs exist in a special and regular relationship with one another. That is, while they are opposed to one another in binary opposition, unmarked signs tend to be inclusive of the marked signs, meaning that unmarked signs can even be used in place of their marked counterpart. Therefore, we should not expect any clear, surface-level relationship between marked and unmarked signs, since we cannot expect marked signs to always be present to signify marked categories. Any attempt to identify whether there is a marked/unmarked relationship between S- and Z-knot sign vehicles must consider a series of scenarios and, from those analyses, address whether or not the evidence remains consistent with the hypothesis of marked and unmarked signs.

Thus, I performed a series of statistical tests to formally assess the statistical significance of S- and Z-knot counts, assessing whether the results of each scenario remained consistent with a markedness relationship. In order to identify whether or not a marked/unmarked relationship existed, it is important to identify whether the number of knot direction signs used for a particular sign type diverges from what would be expected if S- and Z-knot directions were used in an equally probable fashion. While the markedness relationship necessitates some overlap in the use of marked and unmarked items, unmarked items should be clearly distinguished as the primary/inclusive sign of the pairing. In addition, instances where marked signs appear on the same cord as unmarked signs should be clearly distinguished from instances in which unmarked signs appear alone (thereby subsuming the marked category); the latter arrangement emphasizes the binary opposition between the two signifying elements.

Specifically, I performed a series of binomial tests. With each binomial test, I computed the probability of observing larger counts of a particular knot direction than the observed number of knots tied in that direction for each of my series of scenarios (Conover 1971:97:104). I tested against the condition where S- and Z-knots both have a 50% probability of occurring. Therefore, if the number of observed knots tied in a particular direction significantly exceeded my expectations that S- and Z-knots were randomly ordered (i.e., equally probable), the binomial test would return a small probability. If the probability of a value being greater than my observed value was less than 0.05, I took that as evidence that there were a statistically significant number of knots tied in that particular direction.

First, I performed a binomial test comparing the overall count of Z-knots (n=6209) to the overall count of S-knots (n=1704) regardless of knot type (figure-eight, long, or single knot). The binomial test returned a probability of less than 0.0001 that we observe a greater number of Z-knots if the observed knot directions had an equal probability of being tied in the S or Z direction. As an illustration of how slim this probability is, consider Figure 3.5.

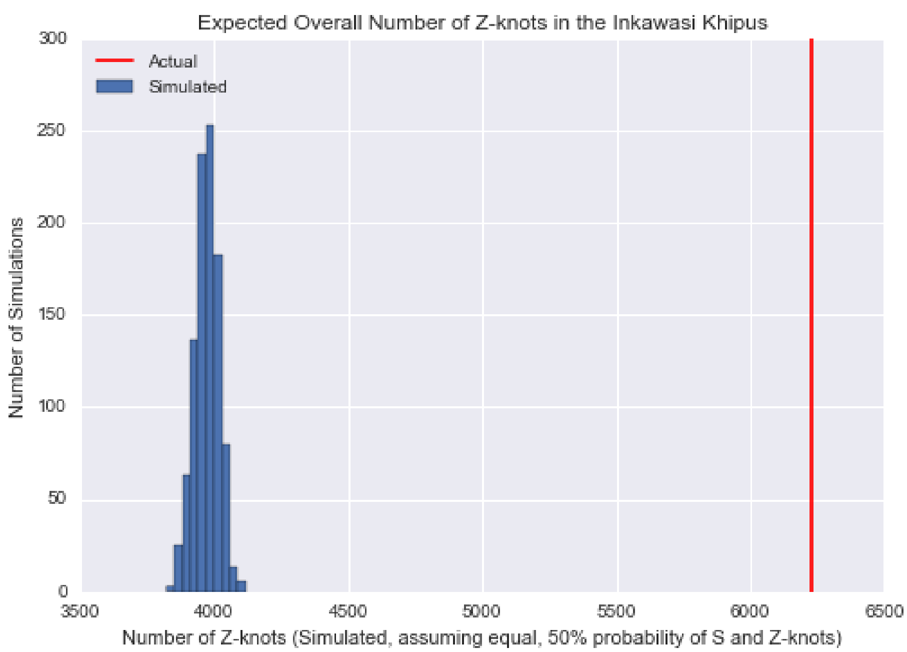


Figure 3.5: *Expected Overall Number of Z-Knots in the Inkawasi Khipus*

I simulated the knot direction of each knot with a recorded knot direction (n=7913), assuming an equal chance of any given knot being tied as an S- or Z-knot. After repeating this simulation 1000 times, notice that the center of the simulated distribution of Z-knot counts is around 4000—roughly half of the overall number of recorded knot directions. The actual number of Z-knots, however, is far outside even the highest bounds of the simulations—thus, the exceedingly low binomial test probability.

Such a disproportionate number of observed Z-knots is what we would expect for an unmarked sign. Furthermore, in conjunction with the results of Figure 3.4, Z-knots seem to have been used systematically to display the (physically) higher, single knots. But if Z-knots match my expectations for an unmarked category, do S-knots match my expectations for a marked category?

Digging deeper into the lower hierarchy knots (figure-eight and long knots), I first considered knots that occurred in the absence of single knots on a cord. When lower-level knots are alone on a cord, there are 402 S-tied long and/or figure-eight knots versus 835 Z-tied long and/or figure-eight knots, which indicates a statistically significant number of Z-knots ($p<0.001$). There seems to be more than meets the eye from this binomial test alone, with long and figure-eight knots often being tied in the Z-knot direction in the absence of a single knot on the cord. We again also see that the count of Z-single knots is highly unlikely to occur by chance alone (1619 Z to 19 S-knots, $p < 0.0001$). Note the difference in ratio between S and Z direction knots from long/figure-eight knots to single knots. Single knots have a greatly exaggerated proportion of Z-knots in comparison to S-knots.

So, what occurs when long or figure-eight knots were tied on the same cord as a single knot? If there was a markedness relationship of binary opposition between S- and Z-knot direction signs based on knot hierarchy, I would expect S-tied long and figure-eight knots to occur alongside a statistically significant number of Z single knots. Because I am proposing a markedness relationship between the two sign types, it should not surprise us to observe either long or figure-eight knots tied in a Z-direction. After all, by definition, unmarked categories can be said to encompass and stand in place of marked categories.

If S- and Z-knots were used as marked and unmarked signs to display knot type hierarchy, however, I would not expect both long and/or figure-eight knots and single knots to be tied in the S direction. Instead, I would expect to see a statistically significant number of Z single knots tied in binary opposition to S long and/or figure-eight knots if S- and Z-knots generally signified a marked/unmarked relationship between the different knot types. Performing another binomial test, I did in fact find that when long and figure-eight S-knots are tied on the same cord as single knots, a statistically significant number of the single knots are tied in the Z direction.

The probability of observing greater counts of Z single knots when long and/or figure-eight knots on the same cord are S-knots (n=1212, in contrast to n=0 for the same scenario with S-knot single knots) by chance alone is extremely slim, with a probability less than 0.0001. Thus, in conjunction with the series of tests supporting the dominance of Z-knots over S-knots and their consistent use at the single knot level, I take this final finding as further evidence that knot direction was used to differentiate knot types at different hierarchical positions, consistent with a marked/unmarked sign pairing in a dicent symbolic way: "single knots *are* unmarked" and "long/figure-eight knots *are* marked."

So, we see evidence of legisign replication, but at what scale? Was this knot direction semiotic strategy just a feature at Inkawasi? Was it limited to the storehouse accounting genre? To investigate further, I performed the same analysis for khipu archives from three archaeological sites with known administrative and storehouse contexts, under the hypothesis that khipukamayuqs at these sites might also have recorded data in a similar way as at Inkawasi. Specifically, I looked at Pachacamac as an exemplar of storehouse accounting (building off of my previous analysis of the khipus at the site in Clindaniel and Urton 2017) and Puruchuco and Armatambo as examples of the related labor accounting genre (see below for more detail about these archaeological sites). I additionally performed the same analysis on the remaining khipus in the KDB where knot direction was recorded.

At Pachacamac, an archaeological site immediately south of modern-day Lima in the Lurín Valley, khipus from across the empire (n=91) were brought with donations for the prominent oracle at the site and deposited alongside each other in storage facilities (Urton 2017: 121). Urton notes that the structural characteristics of the khipus from the site vary widely and likely point to the many different provenances of the khipus. As such, the khipus at the site may be the best sample of storehouse accounting genre khipus in the KDB, because of the likely geographic diversity of khipus at the site.

Additionally, I considered the khipu archive from Puruchuco (n=23), a site on the south bank of the Rimac River. The khipus were excavated from an urn within a small building abutting a large palatial structure and, together with associated balances found at the site, demonstrate the importance of the site as an administrative center for labor accounting (Urton and Brezine 2007:364). I also considered the khipus from the site of Armatambo (n=14) as possible examples of labor accounting khipus. Armatambo is in the immediate surroundings of Lima as well and was transformed during Inka times from an important Yschma site into a major *hunu* level (10,000 tribute payers associated with it) Inka administrative center (Díaz and Vallejo 2002:359). The khipus from Armatambo were found in a funerary context at the site and not directly within any of the administrative compounds (Díaz and Vallejo 2002:370). Finally, I aggregated all of the remaining khipus not from the above provenances remaining in the database where knot direction has been recorded (n=446) and analyzed these as a separate analytical group.

I hypothesized that there might be a "storehouse accounting" or general "accounting" khipu genre. If the knot direction signs described above only were produced at Inkawasi, then I expected that the other storehouse accounting and administrative contexts would all register different results than observed at Inkawasi. If the signs were only produced in a storehouse accounting genre, then I would only expect Pachacamac to register the same results as those observed at Inkawasi. Likewise, if the signs were produced throughout a general accounting genre, but not in other genres in the KDB, I expected to see the remaining khipus in the KDB register different results than those observed in the khipus from Pachacamac, Inkawasi, Puruchuco, and Armatambo. The numerical results and their comparison to those of Inkawasi are recorded in Table 3.1 below.

Evaluating Table 3.1, the patterns at Inkawasi do indeed seem to match overall in both Puruchuco and Pachacamac. Because the Pachacamac archive contains storehouse accounting khipus that are likely from many different geographic locales, it seems that

Table 3.1: *Knot Direction Statistical Summary Comparison by Provenance (*: p<0.05, **: p<0.001 of observing larger result in relation to the other entry in the pair via Binomial Test)*

	Inkawasi	Pachacamac	Puruchuco	Armatambo	Remaining in KDB
Total S knots	1704	1705	241	608**	15461
Total Z knots	6209**	4725**	575**	485	20689**
S Long/Figure Eight Knots (alone)	402	641	217	165	5256
Z Long/Figure Eight Knots (alone)	835**	639	251	227*	7200**
S Single Knots (alone)	19	18	2	187*	3679
Z Single Knots (alone)	1619**	1659**	139**	145	5979**
Z Long/Figure Eight Knot, S Single (same cord)	0	13	8	0	373
S Long/Figure Eight, Z Single (same cord)	1212**	565**	10	29**	715**
S Long/Figure Eight, S Single (same cord)	13	165	0	152**	2603
Z Long/Figure Eight, Z Single (same cord)	987**	910**	113**	43	3728**

across the storehouse accounting genre, knot direction legisigns were replicated in similar ways as those at Inkawasi. Additionally, while we do not know the provenance or genre of all the khipus in the database, notice that the same pattern occurs in the whole of the KDB where knot direction signs are recorded.

Note, however, that where long/figure-eight knots are alone on a khipu cord at Puruchuco and Pachacamac, there is no statistically significant difference between counts of S- and Z-knots. Again, using the same logic as for the Inkawasi knots, this is somewhat expected given the penchant for marked terms in a pairing to be subsumed by unmarked terms (since the unmarked term is inclusive of the marked). Additionally, Puruchuco only features 18 overall cords that feature both S- and Z-knot directions on the same cord, so this particular comparison in the table should be taken with a grain of salt given the small sample size.

While most of the khipus in the KDB agree with the knot direction patterns at Inkawasi, an opposite pattern occurs at Armatambo. At Armatambo, S-knots seem to have been the favored knots to Z-knots overall. For instance, in contrast to the rest of the KDB, instances where all knot positions are tied in the S direction are significantly more common than Z-knot configurations at Armatambo. Furthermore, there are a statistically significant number of single knots tied in the S-direction—opposite of what we would expect under the findings from every other location.

3.4 Discussion

Overall, it seems that khipus across the KDB were produced by replicating standard knot direction legisigns. The S- and Z-knot direction signs seem to have been coded as marked/unmarked hierarchical pairs of dicent symbols. Specifically, the evidence points to Z-knots representing the unmarked (hierarchically superior and inclusive) category and S-knots representing the marked category. Furthermore, such signs functioned as dicent symbols, existing as propositional statements for each knot type at hand.

I make this argument on the basis of observing statistically significant counts of Z-knots for key knot configurations in the accounting khipus from Inkawasi, Pachacamac, and Puruchuco, as well as across the KDB. The only outlier I found was Armatambo – another administrative center, but with a different khipu excavation context than other khipus in the database known to have been associated with administrative facilities (Inkawasi, Puruchuco, Pachacamac). One explanation for this finding may be found in a note Urton and Brezine made about Puruchuco khipus UR66 and UR67. They observed that all of the single knots on UR66 were tied as S-knots, but all the long knots were tied as Z-knots (Urton and Brezine 2007:375-376). They argue that, given the prevalence of Z-knots in matching khipus everywhere else in the archive, systematically manipulating knot direction against the normal rules of knot direction signs might have been a way of signifying that the khipu was a "marked" khipu in a pair—perhaps indicating an intention that it be set aside for a different use-case from the others (i.e. for archival or external circulation). Thus, the khipus at Armatambo might have all been "marked" and set aside in this way—systematically breaking from the standard knot direction legisigns to make distinctions on the khipu-level.

Another explanation for the Armatambo archive's divergence from the rest of the KDB may lie in the fact that the khipus at Armatambo were found in a local, indigenous-style funerary context. While they were found in an Inka phase, the excavators note that the khipus were associated with grave goods that had more local indigenous parallels than they would expect for an Inka bureaucrat from Cuzco (Díaz and Vallejo 2002:370). Given the context of these khipus, it seems plausible that they were not even standard Inka storehouse accounting khipus. Instead, these khipus might have been made using local, indigenous signs to emphasize their owners' social identities. It is possible that the khipus were even made within a different genre that would have been more relevant to the local funerary traditions.

Thus, in general, the knot direction legisigns seem to have been replicated throughout the Inka khipus—conventionalized across the genres and geography represented by the KDB khipus. However, the Armatambo khipu archive hints that there may have been alternative codes being used for certain types of khipus—perhaps just other use-cases under the standard Inka hegemonic semiotic code (as at Puruchuco) or possibly alternative types of recording that reflected the indigenous groups producing them.

My non-Armatambo findings seem to support the notion that Z-knots signified unmarked categories for Inka khipukamayuqs, since they were tied most frequently in the single knot position (i.e. a higher physical, as well as decimal position) and seem to have been considered more inclusive than marked categories. I observed a statistically significant number of single knots tied in the Z-direction, with only very few tied in the S-direction. When S-knots were used by khipukamayuqs, they were generally deployed in long and figure-eight knots in strict opposition to single Z-knots. In particular, I found that when long and figure-eight knots were tied in the S-knot direction, there was a statistically significant number of single Z-knots on the same cord. However, when long and figure-eight knots occurred by themselves on a cord, they often were tied in the Z-knot direction (i.e. they were subsumed by unmarked category). As such, S-knots likely signified marked categories, since the data suggests that they were tied in a more restricted semantic domain, limited to long and figure-eight knots (which was often subsumed by the unmarked domain of the Z-knots).

Urton found that Z-knots occur at a high frequency across all the extant khipus in the KDB (2003), similarly arguing that Z-knots signified unmarked categories and S-knots signified marked categories. Note that these findings are the reverse of Hyland et al.'s knot direction findings from the post-conquest Mangas Khipu Board (2014). In the Mangas Khipu Board, Z-knots were used to signify the marked category and S-knots to signify the unmarked category. While it is possible that the knot direction signing convention used in Mangas was a later, post-conquest development, the difference could also be a matter of genre or a local, indigenous code. Recall that the khipus at Armatambo also featured this reversed usage of knot direction signs and I suggested that those signs could have derived from an alternative code specific to indigenous cord-keeping norms. It is possible that the use of S-knots to signify marked categories and Z-knots to signify unmarked categories was codified only within official Inka khipus, but there were alternative local practices that lived on after the Spanish conquest.

While I noted in the analysis and in my discussion above that a number of long and figure-eight knots are tied in the Z-knot direction–the proposed unmarked sign–this finding is not inconsistent with what we would expect for marked categories. Recall that unmarked signs are said to be inclusive of, as well as primary to, marked signs. Therefore, I argue that Z-knots found at lower hierarchical levels (long and figure-eight knots) could result from what I would term an "inclusion effect." That is, ordinarily marked (S-) knots were transformed into the unmarked sign vehicle (in this case, the Z-knot direction) because they were thought to be included within the unmarked sign.

This inclusion effect occurs on cords within the same khipu, with no apparent location where it tends to occur more than others. It is as if Z-knots became an alias for S-knots on the same khipu, according to the expectations of markedness relations. For instance, if we look at khipus JC009 and JC013 from the Inkawasi archive, there are instances of Z single knots tied on the same cord as S Long/Figure Eight knots, accompanied by other cords with Z single knots tied on the same cord as Z Long/Figure Eight knots. Similarly, while Z Long/Figure Eight knots appear alone on a cord most frequently, there are also instances of S Long/Figure Eight knots alone on cords in JC013. There are no clear additional distinctions between these cords by ply, attachment type, numerical values, or anything else I can identify.

However, none of these arguments address why some decimal positions – i.e., those higher or lower on a cord – might have been marked while others were unmarked. What purpose could marked and unmarked values have served for interpreting the knots? One interpretation is that knot direction might have indicated distinct values on a khipu cord. For instance, the compound number "45" on a khipu cord might not always have referred to a numerical total of 40 + 5 objects, in the sense of Locke's conventional numerical notation. That is, the 40 might have meant one thing, or held one value, while the 5 held another meaning/value. In the hypothetical unmarked/marked relationship I am suggesting here, the 40 might have had a dominant significance (i.e. be composed of 4 single knots tied in the Z-knot direction) in relation to the 5, which would have had a subordinate significance (i.e. be composed of a long knot tied in the S-knot direction).

How might Inka khipukamayuqs have used a differentiation between recorded values on the same cord, like that which is suggested above? There are several possibilities. For example, in the Sector A Inkawasi khipus excavated in the 2013-2014 season, Urton and Chu have demonstrated that there were certain “fixed values” recorded on many of the khipus – that is, numerical values that were repeated over and over in different accounting records. They argue that these values may have represented something like taxes that were placed on goods coming into the storage facility. They suggest that such fixed values (i.e., taxes) might have indicated a quantity of goods that was to be set aside for the support of the storage facility and its personnel (2015:522; 2019). It is thus possible that, in the above example, the number 5 (the marked numerical value on the cord) would have been a tax on the number 40 (the unmarked value on the cord). In other words, the unmarked category could have referred to the quantity of goods brought into an administrative facility and the marked category could have referred to the taxes taken out of this quantity.

However, this interpretation takes several unnecessary logical leaps. The vast majority of known Inka khipu cords (92% of those in the KDB) follow a standard Lockean decimal place system of numerical signification (i.e. only displaying a single overall numerical value per cord; see Chapter 1). Furthermore, as I demonstrated in my analysis above, knots on the same khipu cord are frequently tied in different directions, a pattern that occurs on cords throughout the KDB. Thus, it would seem that marked and unmarked knots were often tied within single compound numerical values (e.g. the compound number 45 in the example above, where 40 is unmarked and 5 is marked). The above taxation theory fails to explain why such widespread patterns of marked and unmarked knots could occur within known compound numerical values in this way.

Instead, it seems more probable that the different knot directions were part of a general principle of numerical notation related to the distinctions that are made between different elements of compound numerical constructions in the Quechua language—the lingua franca of the Inka empire. Urton has noted that in Quechua, compound numbers are spoken with the higher number placed before the lower number. For instance, the number "13" is spoken as *chunka kinsayuq*, "ten, possessor of three" (Urton 1997:46). The notion of the larger decimal unit possessing the smaller non-decimal unit is strikingly similar to the idea of an unmarked category being inclusive of and superior to a marked category. Furthermore, Quechua poetics, which works on the principle of "parallelism," or paired couplets, places great semantic importance on the relationship between, and the spoken order of, the paired terms. Bruce Mannheim argues that the first term in a semantic couplet often takes hierarchical precedence over the second (1986:60). Thus, in reading the numbers on a khipu, we might reasonably assume that a Quechua-speaking khipukamayuq would also consider numbers in terms of complete, unmarked (decimal) units and incomplete, marked numerical units. The Quechua language uses both marked and unmarked signs to represent a single number and S- and Z-knot sign vehicles plausibly could have been used to mirror that existing numerical grammar. In this way, S- and Z-knots would have worked like inflectional signs in a linguistic grammar (i.e. grammatical forms that modify a word to indicate gender, possession, etc.).

Note, however, that in Quechua, the number 110 would be written using the same paradigm as above: *pachaq chunkan* (one-hundred, possessor of 10) (Urton 1997:47). I found no evidence, though, that higher level compound numbers in the khipus were marked using knot direction. In fact, across the thousands of khipu cords in the Inkawasi khipus, I identified only four total instances of single knots on the same cord being tied in different directions (along with 5 at Pachacamac, 0 at Armatambo or Puruchuco, and only 30 across the rest of the KDB). Perhaps these higher-level compound numbers were marked using a different sign vehicle, such as ply direction. Or, perhaps the difference between decimal units and non-decimal units was simply considered to be a more fundamental difference to signify than the difference between multiple orders of decimal units.

3.5 Conclusion

Overall, the knot direction dicent symbolic legisigns seem to have been replicated throughout the Inka khipus—conventionalized across genres and in a variety of different geographical locales. Specifically, S- and Z-knots were used to represent marked and unmarked categories, respectively. I argue that these knot direction signs worked by and large as inflectional signs to mirror the Quechua notion that compound numbers are composed of complete, unmarked (decimal) units, as well as incomplete, marked numerical units. As such, each numerical knot (the subject) was physically linked to a predicate about whether the knot signified a complete decimal unit (unmarked) or not (marked) by alternating the direction in which the knot was tied.

However, while there is evidence of this type of knot direction legisign replication at an aggregate level across the Inka khipus in the KDB, the Armatambo khipu archive hints that there may have been alternative codes used for other sorts of khipus— perhaps just other use-cases under a single hegemonic Inka khipu code or possibly alternative types of recording (or genres) that reflected the indigenous groups producing them. As such, select archives of khipus may have featured contradictory knot patterns meant to signify other processes than the one proposed in this chapter. For this reason, my findings should continue to be evaluated in relation to any additional future khipu archive discoveries from around the Inka empire in order to better understand these alternative codes.

Chapter 4

Deciphering the Logic of Inka Khipu Cord Color Signs

4.1 Introduction

As I discussed in Chapter 1, colors have long been thought to have played an important role in Inka khipu signifying practices. Spanish chronicler testimony, for example, tells us that colors had specific, conventionalized meanings for Inka khipukamayuqs. For instance, recall that Garcilaso de la Vega reported that there was a one-to-one correspondence between cords colored yellow and the metal gold, those colored white and the metal silver, and finally red and warriors (1918[1609]:152). Similarly, Antonio de la Calancha stated that black signified time, that green stood for Inka troops who died during battle, and that red stood for fallen enemy troops, among many other designations (1638:91).

However, more recent khipu scholars have questioned these one-to-one relationships between identities/categories and colors, especially given that so many known khipu signifying practices were fundamentally binary in post-conquest times. For instance, S- and Z-knots were used to encode upper and lower moiety, respectively (Hyland et al. 2014). In addition, S-plied cords have been shown to record unmarked, valued categories and Z-plied cords have been shown to record marked, less-valued categories (Hyland 2014). Given a consistent emphasis on dualistic classification throughout the Andean world, Urton argues that Inka khipu color signifying practices were also likely to have been dualistic and relational (2003:108). Thus, if we want to understand how color worked in khipu semiosis, we need to embrace a more relational notion of color whereby meaning can only be interpreted by looking at any one color in conjunction with other colors. But how exactly would colors have been related to one another for the Inka? How did Inka khipukamayuqs use color to signify information?

Archaeological excavation at the southern coast site of Inkawasi in 2016 and khipu analysis of the broader Harvard Khipu Database (KDB) suggests that color signs did indeed work relationally: khipu cords signified information using combinations of conventionalized color sign pairs, recorded on thread-wrapped sticks. First, I argue in this chapter that these thread-wrapped sticks encoded meaningful pairs of an unmarked, "light" color and a marked, "dark" color. These solid color pairs were then combined to produce a wide variety of more complex color combination khipu cords that offered finer gradations of meaning between the pure light/dark color dichotomy. I argue that these resulting complex color combinations existed in a hierarchical relationship with the two solid colors in each pair. Specifically, these complex color combinations seem to have acted as the "children" or products of the two solid colors. Finally, I demonstrate how dark/light color binaries were used in this way at the site of Inkawasi to signify arithmetic and accounting operations.

4.2 Wrapped Sticks in the Andes

Thread-wrapped sticks were used for several different purposes in the Andes. The Inka may have associated thread wrapping with the prestigious Middle Horizon practices of Wari wrapped cord khipus and thus adapted these signs to their own semiotic purposes (Salomon 2013:22). For instance, Inka burials sometimes contained mummies holding wrapped sticks (Herrmann and Meyer 1993). The chronicler Miguel Cabello Valboa wrote that the last prehispanic Inka ruler, on his deathbed, "made his testament as was the custom. . . putting lines with different colors on a stick, from which they knew his last and final will, and which was given in care to a khipu master" (Cabello Valboa 1951[1586]:393). The practice of wrapping sticks, however, seems to have been a much more ancient practice. Splitstoser, for instance, identified Chavín-inspired wrapped sticks in a burial context at the Paracas site of Cerrillos (Splitstoser 2014).

There is also some precedent for the use of these thread-wrapped devices in traditional

Andean weaving circles. In such communities, weavers use wrapped sticks, called *musa waraña*, as semiotic tools for weaving (Arnold and Espejo 2012:180). In Aymara, the word *musa* refers to an invention or skill and the word *waraña* refers to spilling something (Bertonio 1984[1612]:150, 225). While the literal definition of the term *musa waraña* — an invention or device for spilling something — may seem a bit strange for a semiotic tool, Arnold and Yapita suggest, on the basis of their ethnographic fieldwork, that the word *waraña* can also be used by analogy to refer to copying something down (2006:172). Additionally, Arnold and Espejo suggest that the verb *musaña*, related to the word *musa*, can refer to the action of combining colors well in the context of warping up a loom (2012:180). Related to this meaning of combining colors, *musa waraña* devices are used to standardize specific color combinations and sequences of warp threads in the process of warping up a loom. In present-day weaving communities, certain combinations of colors are associated with specific family lines and ecological zones, and their proper replication is seen as socially essential (Arnold and Espejo 2012:181).

4.3 Wrapped Sticks at Inkawasi and their use as conventionalized color sign lists

In addition to the khipus we excavated at Inkawasi in 2016 (discussed in Chapter 3), we found six thread-wrapped sticks in direct association with the khipus, as well as other khipu production material detailed below. Recall from Chapter 2 that a khipu production site has never been archaeologically excavated in the past. As a result, any speculation about the physical production process of Inka khipus has relied solely on analysis of khipu end-products. Our findings at Inkawasi provide important evidence as to how differently colored khipu cords would have been physically produced, as well as how they would have been made to carry conventional meanings using wrapped sticks. I will briefly describe the khipu production material and then we will return to this discussion of cord production. First of all, the six wrapped sticks that we found appear to be identical to traditional Andean *musa waraña* devices. Consider the wrapped stick in Figure 4.1 (full view) and Figure 4.2 (close-up views).

Figure 4.1: *Wrapped Stick and Pre-made Cord Bundle from Inkawasi Subsector 01, CA 04, UA 04, Cateo 01, UE 03*

Figure 4.2: *Close-up photos of wrapped stick and pre-made cord bundle from Figure 4.1 (Top Left: corresponds to left half of stick in Figure 4.1; Top Right: corresponds to right half of stick in Figure 4.1; Bottom Center: close-up of thread wrappings after the stick was cleaned). Wrapped Stick Colors (see Figure 4.8 for color code definitions) and Wrap Measurements:*
Left-to-Right (Color, with number of times thread is wrapped around stick in parenthesis): MB (9), W (9), AB (9), YB (9), KB (Broken), W (9), MB (9), AB (9), YB (9), KB (9), W (9), MB (9), AB (9), YB (9), KB (Broken), W (9), AB (9), YB (9), MB (9), W (9), AB (9), YB (9).

This stick, wrapped with colored thread, was found on the floor of a swept collca, together with a small bundle of pre-made khipu cords tied to it. Additional wrapped sticks were found on the floors of other collcas, associated with khipus and/or tied together with small bundles of pre-made khipu cords (Figures 4.3-4.5). Full khipus (JC004 and JC005) in Sector B were also found at the base of the collcas in conjunction with cotton fiber in several colors: light brown, dark brown, and white (Figure 4.6). Each of these colors featured prominently within the Inkawasi khipu cords themselves.

Figure 4.3: *Wrapped Sticks (Left: Wrapped sticks in a set of khipu production supplies before cleaning; Right: Wrapped sticks, alone, after cleaning), PAI #1434-2016. Wrapped Stick Colors (see Figure 4.8 for color code definitions) and Wrap Measurements:*
Bottom-to-Top (Color, with number of times thread is wrapped around stick in parenthesis):
Left Stick: YB (9), RL (Broken), PG (12), RL (Broken), YB (10, Broken), PG (12), YB (12), RL (12), PG (12), RL (13), YB (12), PG (12), YB (12), RL (8, Broken), PG (12), RL (12), YB (9, Broken), PG (7, Broken), YB (8, Broken), RL (11, Broken)
Middle Stick: LG (12), (Missing), LG (12), (Missing), LG (10), AB (9, Broken), LG (11), AB (13, Broken), LG (12), AB (10, Broken), LG (10), AB (7, Broken), LG (9, Broken), AB (8, Broken), LG (5, Broken), AB (12), LG (3, Broken), AB (Broken), LG (Broken)
Right Stick: 0B (6, Broken), MB (10, Broken), (Missing), MB (7, Broken), 0B (12), MB (12), 0B (12), MB (12), 0B (12), MB (12), 0B (12), MB (12), 0B (12), MB (12), 0B (7, Broken), MB (5, Broken), 0B (8, Broken), MB (9, Broken), 0B (7, Broken), MB (6, Broken)

Figure 4.4: *Pre-made khipu cords found in the same set of khipu production supplies as pictured in Figure 4.3, PAI #1434-2016*

Figure 4.5: *Contents (after cleaning) of a set of khipu production supplies (wrapped sticks, pre-made khipu cords, and cotton fiber), PAI #1467-2016. Wrapped Stick Colors (see Figure 4.8 for color code definitions) and Wrap Measurements:*
Left-to-Right (Color, with number of times thread is wrapped around stick in parenthesis):
Top Stick: AB (142, Broken), (Missing), W (123, Broken)
Bottom Stick: AB (59, Broken), W (7, Broken), MB (74, Broken), AB (42, Broken)

Figure 4.6: *Photos of diversely colored cotton fiber from JC004/JC005 khipu bundle, PAI #005-2016 (Left to Right: Before and After Cleaning)*

The pre-made cords that were found alongside the wrapped sticks utilized the wrapped sticks' color combinations in their mottled and/or barber pole color combinations. Additionally, pairs of adjacent colors on the wrapped sticks correspond to the same two-color combinations that appear on 83.7% of all color combination khipu cords that are attached to khipus at Inkawasi and 67.4% of all color combination cords in the KDB as a whole. It is improbable that such a correspondence between cord color combinations and the wrapped sticks would occur by chance alone (the probability of observing this many matches by chance alone is less than 0.01; see Appendix A.2 for the calculation). This finding suggests that the wrapped sticks were used as meaningful conventions, or models, for producing color combinations on khipu cords.

Thus, it appears that instead of wrapping thread around the upper portions of pendant cords as the Wari did in order to (presumably) record information on their khipus, the Inka khipukamayuqs wrapped thread around sticks. The Inka khipukamayuqs then integrated pairs of adjacent colors on the sticks directly into their khipu cords through different plying strategies. Consider for instance, the wrapped sticks in Figure 4.3. The sticks are wrapped together by a khipu cord that features a barber pole pattern composed of the colors on the right-most stick (medium brown and olive brown). Found in the same set of khipu production supplies as these three wrapped sticks was the set of pre-made khipu cords in

Figure 4.4.

Note that the middle stick in Figure 4.3 alternates between a light grey and amber brown color. This color combination seems to be reflected in the pre-made khipu cords (Figure 4.4) found alongside the wrapped sticks that are a barber pole combination of amber brown and light grey. In the left-most stick, the repeating pattern is yellow paired with green, yellow paired with red, and finally green paired with red. The pre-made cords contained in this set of khipu production materials also include matching examples of barber pole yellow and green cords, barber pole green and red cords, and barber pole yellow and red cords.

Similarly, moving to another set of khipu production materials in Figure 4.5, we can see similar correspondences between wrapped sticks and pre-made khipu cords. For instance, the barber pole light amber brown and white cords in the bundle of cords at the top of Figure 4.5 mirror the pair of adjacent colors on the left side of the bottom stick (the stick closest to the scale). Specifically, there is a stretch of light amber brown thread wrapped around the stick (approximately 2 centimeters long) followed by a shorter stretch of white thread wrapped around the stick (approximately 0.5 centimeters long) to the right of the light amber brown thread. Thus, it appears that the wrapped stick displays the same color combination as what is found in pre-made khipu cords associated with the sticks.

Furthermore, as I mentioned previously, 83.7% (651 out of 778) of multi-colored khipu cords that are attached to fully-made khipus at Inkawasi display the same color combinations as the color combinations found on wrapped sticks (Appendix A.2). Considering that additional wrapped sticks could have been destroyed by taphonomic processes over time or simply remain unexcavated, 83.7% is a large yield for this small sample of wrapped sticks associated with khipu material (n=6) at the site. Furthermore, four of the top five color combinations observed on the Inkawasi khipu cords occur as pairs of adjacent colors in the excavated wrapped sticks (Appendix A.2). I additionally found, by studying the KDB more generally, that 67.4% (8495 out of 12603) of multi-colored khipu cords that are attached to fully-made khipus display the same color combinations as the wrapped sticks. Mirroring the patterns at Inkawasi, four out of the top five color combinations observed in khipu cords globally are encoded as pairs of adjacent colors in the Inkawasi wrapped sticks (Appendix A.2). Thus, rather than just being a curiosity at Inkawasi, it appears that these color pairings were viewed as conceptually standardized pairings across the khipus in the KDB.

Given all the possible khipu cord colors, though, could not these khipu cord color combinations and matching wrapped stick color pairings have occurred at the observed frequencies by chance alone? To assess the probability that the observed frequencies occurred by chance alone, I performed a Monte Carlo simulation that made random pairings of wrapped stick colors (simulating wrapped stick color combinations from all possible color pairings and calculating the number of successful matches with color combination cords in the Inkawasi archive and across the KDB, by chance alone). The resulting probability that the khipu cord color combinations and matching wrapped stick color pairings occurred at the observed frequencies by chance alone was less than 0.01 for both sets of khipus (Appendix A.2). This finding suggests that the color pairings recorded on the sticks at Inkawasi were being used in a conventionalized way to construct color combination cords not only at Inkawasi, but throughout the Inka empire.

Thus, it is clear that the wrapped stick semiotic technology had relevance for Inka khipukamayuqs. Wrapped sticks at Inkawasi were placed alongside other tools for khipu production on the collca floors of Sector B and used for replicating cord color legisigns. The Inka khipukamayuqs seem to have extended the ancient wrapped stick semiotic technology to record color pairings necessary for the production of khipu cords. Furthermore, the finds at Inkawasi suggest that the khipukamayuqs produced a "bank" of khipu cords from the cotton fiber found at the base of the collcas, combining colors as ordained by the wrapped sticks to produce conventionalized, meaningful cord color signs. Each one of the pre-made cords had already been outfitted with a loop at the top so that they could easily be slid into place and record information once tightened onto the primary cord. Pre-making cords in this way would have made it easier to add information onto existing khipus, especially for cords with complicated color combinations. None of the pre-made cords had knots tied onto them, perhaps indicating that knots were only tied when the cord was about to be attached to a khipu.

Note as well that we only found unspun cotton fiber in natural colors, while some of the premade khipu cords found at Inkawasi employed dyed cotton (e.g. the cords with blue in them in Figure 4.4). It is possible that the dyed fiber and the cords that incorporated dyed fiber were produced elsewhere at the site for the infrequent occasions that khipukamayuqs needed dyed cords. If this were the case, the khipukamayuqs then would have carried these pre-made dyed cords with them, so they would be capable of recording information that the natural colors could not convey.

What specifically did the color conventions recorded on the wrapped sticks refer to, though? Could they have been one-to-one correspondences with words or things like the early Spanish chroniclers reported (e.g. yellow for gold, white for silver, and so on)? Or might the meanings have been more relational, similar to how modern scholars have argued other khipu signs worked?

I argue that, for the khipukamayuqs at Inkawasi, wrapped sticks were used as conventionalized sign-lists that displayed unique, meaningful marked/unmarked color pairings, allowing khipukamayuqs to replicate hierarchically related color legisigns. In order to fully elaborate this argument, we must turn to a discussion of linguistic markedness and its relation to traditional Andean color concepts.

4.4 Markedness and Color Signs in the Andes

Recall from Chapter 1 that the linguistic concept of a marked and unmarked pairing consists of an unmarked sign that is inclusive of and hierarchically superior to the marked sign. I mentioned that such binarism has been shown in ethnohistorical contexts to have been used in khipu signification and I have demonstrated that it was also at play for Inka knot direction signs in Chapter 3.

Importantly for our present discussion of color pairings, marked and unmarked color signs have played a role in a variety of domains in the Andes. For example, for some present-day khipukamayuqs, the color white is associated with masculinity, and the color black is associated with femininity—distinguishing white as an unmarked category and black as a marked category (Arnold 2014:38-40). Urton has argued that this practice similarly extended into the Inka past. Khipu UR28, for instance, features alternating amber brown and medium brown colored cords, which Urton argues represent accounts from the upper moiety (signified with the light, unmarked color amber brown) of the local community and the lower moiety (signified with the dark, marked color medium brown), respectively (Urton 2017:60). Thus, it seems that at least in certain cases, light colors signified unmarked categories and dark colors signified marked categories.

This unmarked/marked distinction between light and dark colors was and is a constant in other Andean semiotic domains as well. Traditionally, for instance, white llamas were said to have been sacrificed to the sun (which was connected to the Inka king) at the beginning of harvest (Cobo 1990[1653]; Molina 1988[1573]) and to have preceded the Inka ruler's caravan (Sarmiento de Gamboa 1942[1572]:40). In contrast, black llamas were said to have been starved and sacrificed during times of crisis (Murra 1978). The distinction between light and dark colors of llamas is similarly emphasized in ethnographic herder descriptions of the llamas, where the various color combinations seen on camelid coats are described using terms that specify the degree to which light and dark colors are combined (Ochoa 1978; Dransart 2002:78; Arnold and Yapita 2001:149). The specific hues of these light and dark elements then modify the terms to specify the particular colors and color combination of the llama in question.

Emphasizing this color duality, Goepfert and Prieto found a Chimu burial with one light colored (beige) llama buried on top of a dark colored (brown) llama (2016:204-206). They argue that these llamas were probably raised for ceremonial purposes as guides in the netherworld (207). Such ritual use of camelids, with an emphasis on their coat, seems to have been common enough that preconquest camelid breeding was closely controlled, in contrast to more heterogenous breeding practices today (Wheeler et al. 1995). Based on the frequency of natural colors found in extant textiles through time, it has been suggested that these breeding efforts increased under the Wari to expand the diversity of natural colors, promoting greater complexity in possible arrangements of light vs. dark (Dransart 2002:143).

Additionally, scholars of present-day Bolivian weaving have found dualistic and hierarchical relationships between light and dark colors in textiles. For instance, Urton found that traditional weavers in central Bolivia classify color hues according to a binary system, with all dyed fabrics deriving from one of two major color categories (called "red/creator rainbow" and "dark/mourning rainbow" respectively; see Urton 1997). Within each major color category are a series of sub-colors that are each hierarchically classified from light to dark (e.g. the sub-color green would be classified from pale green to dark green). Such color hue hierarchies are associated with sound, in the form of microtonal audio changes (Dransart 2016), as well as with the varying colors perceived to form on the undulating surface of Lake Titicaca (Arnold and Espejo 2012).

These principles seem to have been employed in the past as well. Sarah Baitzel argues that Tiwanaku weavers similarly organized their textile band colors into subgroups according to each color's relative lightness and darkness (2016). In the textiles she studied from a funerary bundle in Moquegua, she found that band colors were either woven next to one another because they contrasted with one another (i.e. a light contrasted with a dark color), they were of the same color category (i.e. one light color together with another light color), or they were of the same hue (i.e. a light blue together with a dark blue). Tiwanaku weavers employed each of these three modes of pairing colors to form textile-level symmetrical patterns, reflecting the underlying dualistic principles of Tiwanaku social organization (Baitzel 2016).

In present-day Bolivian weaving communities, Cereceda notes that large bands (*chhuru*) of opposing light and dark solid colors on textiles are often separated, or mediated, by two thin bands (*qallu*) of those same light and dark colors (1986:168). An example of such an arrangement is shown in Figure 4.7.

The weavers tell Cereceda that these thin, mediating bands form a category between the "masculine" light color and the "feminine" dark color—considered to be the "offspring" of the light and dark bands (Cereceda 1986:169). This thin-striped combination of light

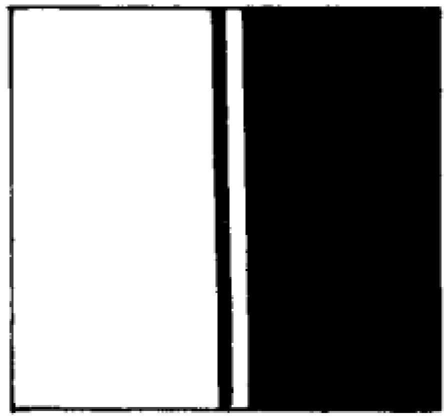


Figure 4.7: *Illustration of large chhuru bands separated by thin qallu bands on a textile (from Cereceda 1986:160)*

and dark is said to appropriately contrast the solid hues and to mediate the dark and light. These "children" are thus distinguished from both of the solid colors, acting as a unique intermediary between them. Note that this logic mirrors that of the Quechua ontology of numbers, where multiplication, or increasing ontological complexity, is seen as reproduction between two elements, which usually stand in a marked/unmarked relationship to each other (Urton 1997:161). Transitional colors can then be hierarchically conceived as more marked than light colors, but less marked than dark colors. For an example of this hierarchical relationship between colors in the past, consider the Inka ceque system that was introduced in Chapter 1, and the three categories by which the ceques were ranked, from *collana* at the highest rank, to *payan*, in the middle, and finally *callao*. In Zuidema's reconstruction of the system, *collana* was associated with white, *payan* was associated with the color combination of white and black, and *callao* was associated with black (Zuidema 1964:104-105, 138-139). In this Inka ceque system arrangement, white corresponded to the unmarked category *collana*, black to the marked category *callao*, and the color combination of white and black to the intermediary category *payan*, which ranked between *collana* and *callao*.

The coming together of complementary opposites in sex, ritualized war, and so forth to produce something new, a new synthesis, is commonly referred to as *tinku* in Quechua

(Platt 1987:164). We might similarly conceive of the meeting of two solid colors in Cereceda and Zuidema's examples as instances of *tinku* (i.e. new categories produced by, but set apart from, the opposing solid colors). Such *tinku* color categories then exist as intermediary categories between their unmarked (light) and marked (dark) solid-color parents.

Thus, we have seen that in a variety of traditional Andean semiotic domains, solid light and dark colors were, and continue to be, seen as conceptually opposed and hierarchically related to one another. In addition, syntheses of these colors—*tinku* color combinations of light and dark colors—act as conceptually distinct intermediaries between the two solid colors. Let us now turn back to the Inka khipus and investigate how this logic of light and dark colors also informed the production of Inka khipu color signs.

4.5 Color Hue Markedness in the Inka Khipus

Overall, in the Inkawasi khipu archive and the KDB at large, there are hints of an aggregate relationship between light and dark colors similar to that which we saw in the ethnohistorical and ethnographic materials/examples discussed in the previous section. To evaluate the usage of light and dark colors at an aggregate level in the KDB, I turned to a color scheme that former KDB manager Carrie Brezine designed to organize khipu cord color categories in the KDB (Figure 4.8).

Colors are organized from top to bottom in the diagram by hue (from light to dark: yellows and reds to greens and blues), with compound colors beneath them, based on how much black they integrate (from those that integrate the least black, to those that integrate the most). In the left-to-right direction, the scheme accounts for the shade of each one of these colors (i.e. the incorporation of more black or white within a given hue). For instance, a red/yellow/blue composite makes the color brown, meaning it is closer to the bottom of the diagram in terms of hue and can be shaded darker or lighter (in the left-to-right direction) by adding more black or white to it, respectively. Additional complex color combinations are arranged even further down in the diagram by integrating even further amounts of the color black.

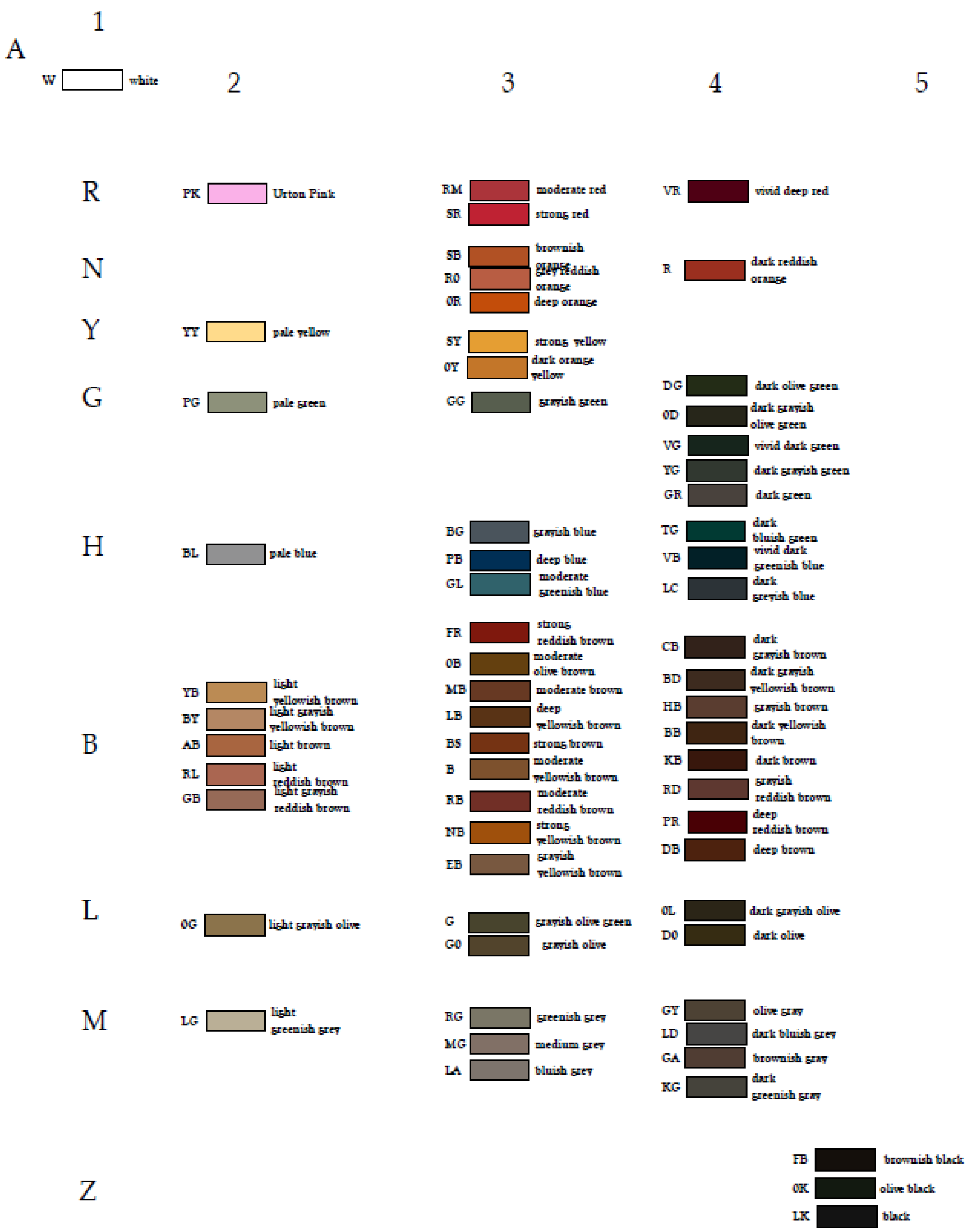


Figure 4.8: *Brezine Khipu Color Scheme Chart*

With this diagram in hand, I scored each solid colored cord in the KDB on a 10-point scale based on the order of hues and shades in Brezine's color scheme (see Appendix A.2 for the specifics of how this scale was calculated). My goal was to identify whether solid colored cords tended to be light-colored or dark-colored. If light-colored cords were used to signify unmarked categories and dark-colored cords were used to signify marked categories, I would expect cord colors to be lighter overall. After all, unmarked signs are, by definition, semantically inclusive of marked signs (i.e. unmarked signs can stand in place of marked signs) and should, thus, occur more frequently.

The cutoff for what constitutes "light" and "dark" colors is culture-specific, however, and difficult to evaluate on a purely quantitative scale. Therefore, to derive a plausible cutoff, I identified khipu cords in the KDB that had multiple colors in them. Then, I calculated two scores for each one of the color combination cords, using my 10-point scale. First, I scored the lightest color in each one of these color combination cords. Then, I scored the darkest color in each one of the color combination cords. My assumption was that these two colors would have been seen as distinct (i.e. one lighter than the other) by the khipukamayuq who made the color combination cord, or else the colors would not have been used in a color combination cord. In the analysis, I called the lightest portion of the color combination cord the "tinku light" color and the darkest portion of the cord as the "tinku dark" cord, as they represent a meeting of light and dark colors, similar to the meeting of complementary opposites described by the concept of *tinku* earlier in this chapter.

Overall, my analysis (Appendix A.2) suggests that solid colored cords tend to be light-colored more often than they are dark. Solid colored cords at both Inkawasi and globally across the KDB are closer in their color score to the "tinku light" colors. Specifically, the absolute mean difference between solid color scores and "tinku light" color scores (Inkawasi: 1.119, KDB: 1.891) is less than the absolute mean difference between solid color scores and "tinku dark" color scores (Inkawasi: 1.548, KDB: 1.975). Furthermore, the probability of observing this large of a chasm between the two absolute mean differences by chance alone is less than 0.05 at Inkawasi and less than 0.06 globally across the KDB. Thus, at least at an aggregate level, these findings suggest that light colored cords signified unmarked categories and dark colored cords signified marked categories.

So, how do the color combination cords and wrapped sticks fit into all of this? I argue that in the same way that light and dark colors and their combinations relate to one another in other Andean mediums, khipu color combination cords worked as intermediaries between unmarked (light) and marked (dark) solid cord color categories. As I demonstrated earlier in the chapter, each color pairing on a wrapped stick would have allowed khipukamayuqs to replicate color combination legisigns on a cord. Additionally, though, I argue that these wrapped sticks would have been relevant to solid colored cords, in that one of the colors in each pairing would have been conceived as light (unmarked) in relation to the other, which would have been conceived as dark (marked). As such, each pair of colors on a wrapped stick would have encoded the relationships between a "family" of hierarchically related signs, from the (unmarked) light color sign (the lighter color in each pair), to the intermediary color combination signs (combinations of the two solid colors in the pair), to the (marked) dark color sign (the darker color in each pair).

But if colors on a khipu were seen as operating according to a primarily tripartite logic (unmarked, intermediary, and marked), why would there be multiple different and distinct ways of combining colors in a khipu cord? Let us begin to address this question by sketching out the logic for the two most common color combination cord types at Inkawasi: barber pole and mottled cords. Recall from Chapter 1 that barber pole cords have the appearance of an old-fashioned barber pole, and are formed by plying a cord such that multiple colors join together in an interlocking spiral. Mottled cords, on the other hand, are plied so as to produce a seemingly random arrangement of colors throughout the cord.

Considering only the mottled and barber pole methods of combining colors in a khipu cord, we have four unique color signs for each pairing of marked/unmarked colors on a wrapped stick. Rather than being a coincidence, I argue that the semiotic logic of having four fundamental color signs (light solid color, barber pole, mottled, dark solid color) per sign-grouping makes sense as a complete representation of the Quechua concept of *yanantin*, or symmetry between complementary opposites. Platt describes how the logic of asymmetrical dualism and reproduction discussed by Cereceda can give birth to two further categories. Specifically, he argues that *yanantin* can be defined as "Helper and helped united to form a unique category"—in short, marked and unmarked brought together to form an intermediary (1986:245).

In his 1986 case study of Macha semiotic logic in Bolivia, Platt finds that the fundamental logical units of the Macha cultural universe are dual and hierarchical (specifically, he discusses the unmarked/marked categories of man vs. woman and right vs. left). However, because each of these fundamental units can be mirrored (and thus provide a complementary opposite for the original), there are actually four logical units within the ideal of *yanantin*: male, male-female (the mirror image of male), female-male (the mirror image of female), and female (Platt 1986). This quadripartite conceptualization explains, for example, why local men can engage in *tinku* ritual battles with one another (a male and a male-female) and women can engage in *tinkus* with one another as well (a female and a female-male)—their mirror completes them and produces a fundamental symmetry between them. In the sense of markedness, we might think about these mirror units as marked in relation to one of the categories in a quadripartite logical set, but unmarked in relation to another. For instance, male is unmarked in relation to male-female, male-female is unmarked in relation to female-male, and female-male is unmarked in relation to female. All in all, the original unmarked/marked relationship between male and female produced a hierarchically ranked set of four fundamental conceptual units. Such a quadripartite model of reality maps onto domains from the Inka empire as well. Recall from Chapter 1, for instance, that the four suyus of Tawantinsuyu were also hierarchically ranked, based on a foundational logic of binary opposition. Chinchaysuyu and Antisuyu belonged to the upper-ranked, unmarked, *hanan* portion of Cuzco, whereas Cuntisuyu and Collasuyu belonged to the lower-ranked, marked, *hurin* portion of Cuzco.

If we accept that frequency of use is a proxy for identifying markedness—as we would expect unmarked signs to occur more frequently than marked signs—then we can begin to empirically assess how barber-pole and mottled cords fit into the overall asymmetrical sign hierarchy of color combination signs that I have theorized. In Table 4.1, we can see that mottled cords are in fact more common than barber pole cords, both globally in the database as well as locally at Inkawasi. As we would expect, solid cords are more common

Table 4.1: *Frequency of Cord Color Sign Types in Inkawasi Khipus and Globally in the Khipu Database*

	Inkawasi	Khipu Database
Solid	4728	41699
Mottled	572	10582
Barberpole	254	2495
Solid/Solid	25	1001
Mottled/Solid	78	682
Barberpole/Solid	18	187
Mottled/Mottled	13	160
Mottled/Barberpole	5	27
Barberpole/Barberpole	4	38

than mottled and barber pole cords combined. Earlier in the chapter, I argued that light color cords were higher ranked than dark color cords. Thus, we might hypothesize then that the hierarchical relationship between these four fundamental color categories worked as follows (ranked highest to lowest): Solid light color, Mottled, Barber pole, Solid dark color. The mottled and barber pole cord color types would, therefore, conceptually be the offspring of solid light and dark colors, since they include both the light and dark colors within them. Mirroring the ethnohistorical and ethnographic accounts for colors, these color combination cords also appear capable of having acted as intermediaries in the cord color type hierarchy between the solid color cord types.

Such four fundamental units could theoretically represent numerous aspects of the social organization of the Inka empire. For instance, it would be possible to represent complex quadripartite divisions that existed in hierarchical relationships like the *suyu* segments of the Inka empire using the aforementioned four fundamental cord color types. Additionally, tripartite divisions like those that organized the ceque system, discussed earlier in this chapter, could have been signified using three of the four cord color types (light solid, mottled, and dark solid, for instance). It would have, thus, been possible for Inka khipukamayuqs to represent dual, tripartite, and quadripartite divisions with these four fundamental cord color types alone.

What should we make of cords that change color part-way through the cord? Recall from Chapter 1 that there are actually three ways of combining multiple colors on a cord: patterns resembling the color spiral of a barber pole, mottled patterns with seemingly random color variation within a cord, and finally cords that feature complete color changes part-way through the cord. How should these color-change cords be conceived in this overall logic of cord color signs? Color-change cords are the rarest of all the cord color types, produced by combining the aforementioned four fundamental color sign types (solid, mottled, barber pole) at different vertical levels along a single cord to bring additional conceptual granularity and complexity to the cord. As shorthand, khipu scholars will use the "/" to indicate a change from one color to another over the course of a single khipu cord (for instance, W/MB means that the top of the cord was solid white and the bottom of the cord was solid medium brown).

By employing color-change signs, khipukamayuqs could have further refined the four fundamental cord color types (light, mottled, barber pole, dark) to refer to up to an average of 16 conceptually-linked ideas for each pair of colors (assuming the KDB average of 2 color types along the course of the cord, the number of possible combinations of the fundamental four color types is 4!/(4-2)! + 4 = 16). If we organize these cord color combination types as "offspring" in a family tree like Cereceda indicated color combinations were conceived in Bolivian weaving communities, we might hypothetically think of them as displayed in Figure 4.9, where there is a distinct familial hierarchy to signs that derive from the same pair of solid colors.

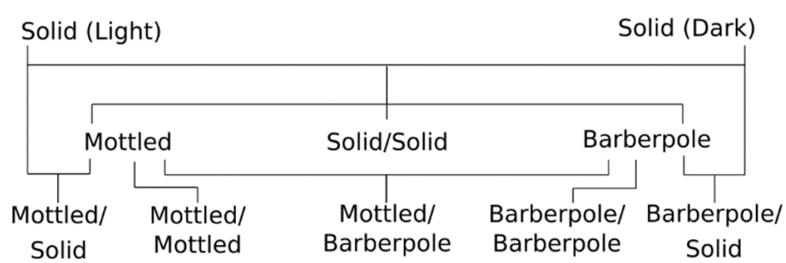


Figure 4.9: *Cord Color Combination Family Tree*

In the diagram, I continue to use the "/" character to designate color changes within cords. For instance, a cord that transitions from a mottled color combination to a solid color would be labeled Mottled/Solid in Figure 4.9. Note that color-change cords are the offspring of both the original light and dark colored cords as well as the mottled and barber pole cords.

The various ways of pairing colors and allowing them to “reproduce” or multiply, gave khipukamayuqs the ability to represent the complex markedness relationships that made up their social world. However, while this impressive sign capacity would have been possible, it seems likely that khipukamayuqs expanded their cord color sign families only so far as they needed in order to signify a set of conceptually-linked ideas. For instance, a family of six conceptually-linked ideas could have been signified on a khipu with a two-color pairing by adding only two additional distinctions to the existing four fundamental cord types. It would seem reasonable for khipukamayuqs to add these two additional distinctions by employing the two highest ranked color-change cord types. Based on the frequency of these signs overall in the KDB (see Table 4.1), it seems that the order in which additional color types (beyond the fundamental four discussed above) would have been ranked was solid/solid (the highest ranked of the third generation children), all the way down to barber pole/barber pole (the lowest ranked of the third generation children).

Note that the Inkawasi archive only rarely features two solid colors in a color-change cord, but the KDB shows this pattern a great deal more than the other types of color-change cords (suggesting that this type of color-change cord is the highest ranked of the color-change cords overall, but was not used for some reason at Inkawasi). The remaining color-change categories follow the pattern we would expect given the markedness characteristics of the four fundamental color combination types. For instance, barber pole cords were ranked lower than mottled cords, so the solid/mottled color-change category tends to be more numerous than the solid/barber pole color-change category. However, notice that the expected order is reversed between the mottled and barber pole and multiple barber pole categories, which have too few instances (both globally and at Inkawasi) and are too numerically close to one another to adequately assess.

In summary, Inka khipukamayuqs at Inkawasi and across the empire seem to have referenced marked/unmarked symbolic color pairings encoded on wrapped sticks to produce cord color signs. I have additionally suggested that color pairings were combined and ranked according to a standard logic. Specifically, I argued that color combination cords could have been used to signify finer gradations of ranked, hierarchical meaning than marked/unmarked solid color pairs would have been capable of on their own. We thus have a theory for how the logic of cord color signs worked. But how did the cord color signs work in practice? Does this theoretical treatment get us any closer to deciphering what the cord color signs actually mean? To answer these questions, let us turn to a demonstration of cord color-based signification at Inkawasi.

4.6 Proof of Concept: Signifying "Credit," "Debit," and "Result" with colors

In 2015, Urton and Chu demonstrated the use of “fixed values” in the khipus found in Sector A at Inkawasi—that is, numerical values that were repeated over and over in different accounting records. They argue that these values may have represented something like taxes that were placed on goods coming into the storage facility, as the numbers seem to have been involved in many subtractive arithmetic operations. For instance, in the first three cords of UR267A, the numbers 106, 15, and 91 occur in sequence. This sequence of numbers can be algebraically balanced by the mathematical operation of subtraction: “106-15=91.” Similar subtractive operations occur again and again throughout the khipu and Urton and Chu suggest that these fixed values (i.e., taxes) might have indicated a quantity of goods that was to be set aside for the support of the storage facility and its personnel (2015:522).

In reviewing these findings, however, I discovered that these sequences of arithmetic operations were not merely implied in the khipus by the numerical values themselves. To the contrary, the sequences of arithmetic operations were explicitly denoted through the use of cord color, by means of the principles I have already laid out in this chapter (see Table 4.2). Specifically, in cords 1-3, you can see that the color white (W) was used to designate addition (credit), the color amber brown (AB) was used to designate subtraction (debit), and the mottled color combination of amber brown and medium brown (AB:MB) was used

Table 4.2: *Cord Color and Numerical Data from Inkawasi Khipu UR267A*

Cord Number	Cord Color	Color Meaning	Number on Cord
1	W	Addition, +	106
2	AB	Subtraction, -	15
3	AB:MB	Result, =	**91**
7	W	Addition, +	161
8	W	Subtraction, -	15
9	AB:MB	Result, =	**140** *Broken
11	W	Addition, +	206
12	W	Subtraction, -	15
13	AB:MB	Result, =	**191**
14	W	Addition, +	238
15	W	Subtraction, -	15
16	W	Result, =	**223**

to designate the result of the arithmetic operations. For instance, the first cord on UR267 has the value 106 recorded on it and is colored white. The second cord has the value 15 recorded on it and is colored amber brown. The third cord of the sequence is colored AB:MB (i.e. mottled) and has the resulting value 91 recorded on it. Therefore, the operations as designated by the colors would be: "+106-15=91."

Note, however, in Table 4.2 that after establishing the sequence of arithmetic operations for the khipu with the sequence of W, AB, and AB:MB, there is an inclusion effect similar to the one described in Chapter 3. The second entry maintains the meaning of subtraction, but the marked color AB (used for subtraction previously) has been replaced by the more inclusive, unmarked color W. For cords 7-13, the AB:MB "result" cord color remains unchanged, however, to establish that this number is still the result of the previous two numbers. Finally, for cords 14-16, even the AB:MB cord is included within the unmarked W color and the operations continue on in the same sequence, under the alias of the unmarked color W. It seems that the khipukamayuq used the colors initially to establish the sequence of arithmetic operations, but no longer felt the need to designate these colors after that sequence had been established.

Given the tendency for light colors to be associated with unmarked categories and dark colors to be associated with marked categories in a wide variety of Andean semiotic contexts, this choice of colors makes a lot of sense: summation is, by definition, superior in an additive, constructive sense and thus unmarked in relation to the arithmetic operation of subtraction. Note that there is some precedent for the use of marked and unmarked khipu signs to designate arithmetic operations like addition and subtraction. For some present-day khipukamayuqs, S-ply is conceived as "giving" (i.e. corresponding to subtraction, the marked operation), and Z-ply is seen as "receiving" (i.e. corresponding to addition, the unmarked operation; see Arnold 2014:40-41). As I mentioned earlier in the chapter, color combination signs seem to have been used to signify intermediary categories between marked (signified by a dark color) and unmarked (signified by a light color) categories. Here, we have a mottled cord, which I argued is the highest ranked of the various cord color combination options available to a khipukamayuq (and, thus, probably the first to be chosen to represent an intermediary category). In this case, the mottled color combination sign seems to fittingly refer to the synthesis of addition and subtraction, or the arithmetic result of the two operations.

The use of cord colors gets even more complex when we look to khipu UR255, however, which Urton and Chu argue is a "matching" khipu to UR267A (2015:522). As Urton and Chu demonstrate, the numbers in UR255 seem to be organized so as to perform the opposite sequence of arithmetic operations from those performed on UR267A. Urton and Chu propose that this would have been a way for khipukamayuqs to cross-check their calculations in UR267A. So, for example, in cords 67-69 of UR255, we see the sequence: 70, 55, 15. Here, the khipukamayuqs seem to have switched the order of arithmetic operations so that the fixed value/tax is the result: "70-55=15."

Looking at Table 4.3, the first thing you should notice is that the vast majority of the cords on khipu UR255 are colored AB—the marked color on UR267A that signified subtraction. Unlike in khipu UR267A, the color AB does not seem to have been used to signify subtraction in the UR255 khipu, however. Instead, it seems to have been juxtaposed with the color Medium Brown (MB). Since AB is the lighter color of the pairing (i.e. the unmarked color),

Table 4.3: *Cord Color and Numerical Data from Inkawasi Khipu UR255*

Cord Number	Cord Color	Color Meaning	Number on Cord
47	AB	Addition, +	187
48	AB		0
49	AB	Subtraction, -	15
50	AB:MB	Result, =	**172**
51	AB	Addition, +	141
52	AB	Subtraction, -	126
53	AB	Result, =	**15**
54	AB	Addition, +	127
55	AB	Subtraction, -	112
56	AB	Result, =	**15**
57	AB	Addition, +	110
58	AB	Subtraction, -	95
59	AB	Result, =	**15**
60	AB	Addition, +	148
61	AB	Subtraction, -	133
62	AB	Result, =	**15**
63	AB		0
64	AB	Addition, +	201
65	AB	Subtraction, -	186
66	AB	Result, =	**15**
67	AB	Addition, +	70
68	AB	Subtraction, -	55
69	AB	Result, =	**15**
70	AB	Addition, +	92
71	AB		0
72	AB	Subtraction, -	15
73	MB:AB	Result, =	**61**
73, Subsidiary 1	MB	Subtraction, -	16

it played the role of addition on this khipu and MB played the role of subtraction. Finally, as in khipu UR267A, AB:MB designated the result. As in khipu UR267A, these colors only seem to have been used, however, to establish the sequence of arithmetic operations where it was otherwise unclear. Note that the strings of repeating arithmetic operations listed in Table 4.3 are all signified using the color of the highest ranked color on the khipu: AB. However, when the khipukamayuqs needed to reestablish the order of arithmetic operation or clarify the meaning of a particular sequence of operations, they used the MB and AB:MB color sign vehicles.

For instance, note that the order of arithmetic operations is different for cords 47-50 than for 51-69 and there is a blank, unused cord that could potentially confuse the arithmetic: 187-15=172. To make these operations clear, the khipukamayuq designated the result "172" using the AB:MB color that we now know signifies resulting values on these khipus. Similarly, in cords 71-73, the operations were a bit out of sequence. Here, the khipukamayuq again used an AB:MB cord to signify the resulting value of additions and subtractions and added an additional MB cord onto the "result" cord to signify an additional subtraction (the marked color in comparison to unmarked AB), leading to the correct resulting value.

Such patterns begin to make some sense of the wrapped stick in Figure 4.2 (see the close-up of the thread wrappings after cleaning at the bottom of the figure). While there are many color combinations on the stick, notice that there are sequences of the colors W, AB, and MB—the color oppositions khipukamayuqs referenced in order to produce the color signs for the arithmetic operations in khipus UR267A and UR255.

It seems plausible that each stick acted as a sort of unified "topic" with lists of marked/unmarked color pairings that could have been used within a particular genre to produce meaning. For instance, in UR267A, W signified the unmarked action of "addition" and the paired color AB signified the marked action of "subtraction." In UR255, AB signified the unmarked action of "addition" and the paired MB signified the marked action of "subtraction." For both the khipus, the color combination AB:MB signified the "result" of addition and subtraction.

The use of two different color pairs to signify the same arithmetic operations (addition, subtraction, and their result) suggests, though, that Inka khipukamayuqs did not only utilize marked/unmarked color pairs to designate cord-level arithmetic operations. Rather, they also likely used marked/unmarked color pairs to make khipu-level distinctions, like signifying the type of calculation each khipu in a matching pair recorded: net credit or net debit calculations. Khipu UR267A, for instance, seems to have recorded operations that result in after-tax, "net credit" values. Khipu UR255, on the other hand, recorded the arithmetic operations in the opposite direction, resulting in the taxed values, or "net debit" values. As I stated above, Khipu UR267A employed W as its unmarked color to signify addition and AB to signify subtraction. UR255, in contrast, used AB as its unmarked color to signify addition and MB to signify subtraction. Note that these color pairings (W and AB as well as AB and MB) stand in a marked/unmarked relationship to one another. W is unmarked in relation to AB (as seen in UR267A) and AB is also unmarked in relation to MB (as seen in UR255). Thus, the choice of an unmarked color in a color pairing would have made a difference in how that pairing related to color pairings on other khipus through markedness relations. For instance, the use of white as the unmarked color sign in UR267A reflects the khipu's unmarked, additive characteristics in contrast to use of amber brown as the unmarked color sign in UR255, which reflects the khipu's marked, subtractive characteristics overall.

In this way, the overall color scheme of a khipu could act as a marked or unmarked sign, predicating the khipu as a whole with information about the type of calculations that were done on the khipu. Therefore, in brief, at a khipu-level, the use of white as the unmarked color sign in UR267A signified that the khipu recorded "net credit" calculations, whereas the use of amber brown as the unmarked color sign in UR255 signified that the khipu recorded "net debit" calculations. The combination of multiple conventionalized color binaries on a wrapped stick would have made it possible for a khipukamayuq to signify nested levels of meaning (i.e. both at the khipu-level and the individual cord-level) by hierarchically relating color pairings to one another in the way I have explicated above. Theoretically, then, these nested, color-based meanings could have been correctly interpreted by anyone familiar with the code on the relevant wrapped stick.

In summary, I have demonstrated how marked/unmarked color pairings were used at Inkawasi to signify non-numerical values (i.e. arithmetic and accounting operations). The light color of each color pairing was associated with an unmarked operation (addition) and dark color with a marked operation (subtraction), as I expected based on my aggregate-level findings earlier in the chapter. Also, as theorized, color combination cords were conceived as the synthesis, or offspring, of the two solid colors in a color pairing—in this case, the synthesis of addition and subtraction.

Note, however, that to date, I have yet to identify other storehouse accounting khipus that employ this same system of color corresponding to these same arithmetic actions. It is possible that the colors on a khipu are particular to the archive at hand (and/or the wrapped stick that the colors were coded by), rather than to the genre, or some other global indicator. Perhaps the only common convention between different khipu production contexts was the use of the same marked/unmarked color pairings to signify information. The scale of conventionalized sign production very well may have been limited to the use of a particular wrapped stick, while the logic of the color sign markedness was more universal. Or perhaps, khipus UR267A and UR255 at Inkawasi belong to a unique type of accounting khipus that has not been previously found in the KDB. Whatever the case might be, it seems likely that the logic of these color signs would have carried over to other binary color pairings. Moreover, other color pairings would have likely been capable of signifying additional conceptual relationships, beyond arithmetic operations alone, using the same semiotic principles identified here.

Urton notes that Spanish transcriptions of Inka tribute lists recorded on khipus recounted combinations of activities on cords: for instance, using the verbs *sacar* and *llevar*, "The gold that they took they delivered to Cuzco" (1998). He suggests on this basis that khipu cords could have recorded two different forms of action/verbs on the same cord (1998:425). As we have seen with the actions "to add" and "to subtract," color can be used to accomplish this purpose, with the light color in a family of related colors used to signify addition and the dark color used to signify subtraction. When the two colors were mottled together on a cord, this signified the combination of "to add *and* to subtract," i.e. the result of the arithmetic operations. Other color combinations could have formed additional verb combinations, such as the examples Urton provides.

In summary, we can see that the colors worked as dicent symbols at Inkawasi, acting as predicates for the cords, and designating the kind of arithmetic action to be done for each number on the khipu in participle form (W: "___ was added," AB: "___ was subtracted," AB:MB: "___ was the result," or "___ was added and subtracted"), rather than leaving it to memory or implication. Furthermore, in a fashion consistent with the dicent symbol sign type, the subject (the number recorded on the cord) was physically modified by the cord color, thereby linking it to the predicate.

4.7 Conclusion

I have argued that the colors on wrapped sticks found at Inkawasi were used as sign lists, or models, for replicating marked and unmarked cord color signs on the khipus at the site. Additionally, analysis of the KDB suggests that the color pairings on the Inkawasi wrapped sticks were well-represented across the database and likely also conventionalized as marked/unmarked pairs. Furthermore, I demonstrated in a close study of Inkawasi khipus UR267A and UR255 how dark/light color binaries were used as marked/unmarked pairs of dicent symbols to signify arithmetic operations and suggested how they might generally have been used across the database to signify other actions and concepts.

Close study of the rest of the khipus in the database, combined with other excavated wrapped sticks, however, is necessary in order to make further progress as to the meaning of other colors and the universality of particular color pair meanings. Additionally, because of the wrapped sticks' connection to traditional Andean weaving, we might expect there to be some crossover with the semantics of warp color combinations. We might be able to decipher further color signs in the khipus by close study of these warp color combinations and their semantic meanings (potentially unlocking the complex verb combinations on cords hinted at in Urton 1998). In short, all of this affirms that color signs from a variety of Andean domains were intimately connected and a continued conversation between weaving, khipu studies, and camelid pastoralism is essential in order to make further progress in deciphering khipu color signs.

We can see that khipu color markedness was more complex than the single binary pairings seen in domains like knot direction, ply direction, and attachment type. Marked (dark) and unmarked (light) colors could be combined together on a single cord to form further complex categories, signifying additional categories in relation to the original pair. These intermediary colors would have allowed khipukamayuqs to create up to 4 conceptual distinctions for any marked/unmarked color pairing: solid light, solid dark, barber pole, and mottled. These distinctions could then be broken down into even finer grain divisions (an average of 16). Thus, while marked/unmarked binary signs formed a logical basis for Inka khipu signification, color signs could expand into higher order semiotic groupings based on the same principles. This semiotic system would have made it possible to effectively represent the hierarchical relations in established Inka tripartite and quadripartite conceptual divisions (such as the the social and political structures of the empire), as well as conceptual divisions between verbs or actions.

It is still unclear, however, at what scale particular color signs would have been meaningful. It appears, from analyzing the KDB, that the pairs of color signs identified in the Inkawasi wrapped sticks appear in other locales. While arithmetic operations were signified using the colors W, AB, and MB at Inkawasi, though, I have been unable to find other relevant examples, to date, that use these exact colors in this same way. It is possible that certain color signs were only meaningful in the context of a particular archive, genre, or set of wrapped stick color codes. Further research into other color combinations at Inkawasi and across the khipus in the KDB is necessary in order to address any of these concerns more definitively.

Chapter 5

Investigating the Role of Color Banding and Seriation in Inka Khipu Semiosis

5.1 Introduction

In Chapter 4, I argued for a more relational approach to deciphering the meaning of cord color in Inka khipus. In addition to looking at individual khipu cords and interpreting the color families used to construct meaning at the relatively microscopic, cord-level of analysis, another important approach is to focus on khipu color patterns as a whole at the macroscopic, khipu-level of analysis.

Khipu scholars have long recognized that the color patterns made by adjacent pendant cords on a khipu also have the capacity to signify information. Two of the most common color patterns khipu scholars encounter on a khipu are called "color banding" and "color seriation" (see Figure 5.1).

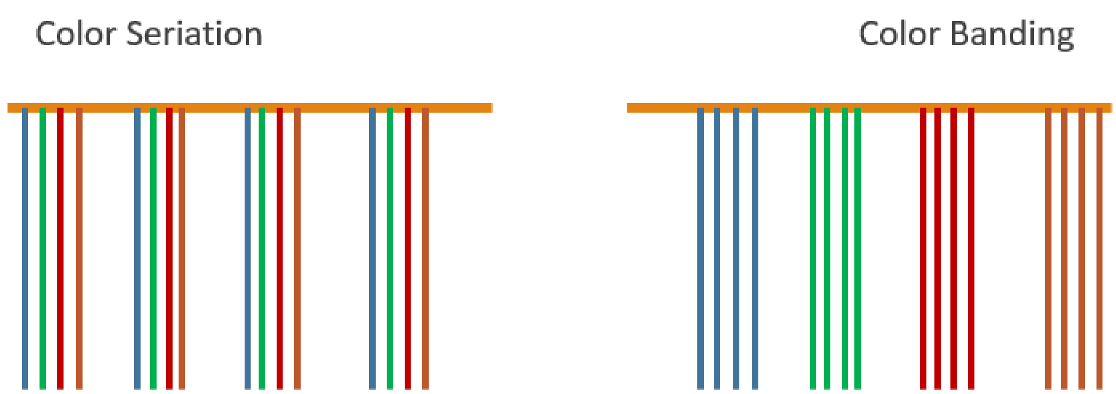


Figure 5.1: *Illustration of Color Seriation and Color Banding*

Recall from Chapter 1 that color seriated khipus each feature a sequence of differently colored pendant cords repeated multiple times within the khipu. Thus, the seriated khipu in Figure 5.1 is a four-color seriated khipu. It features a sequence of blue, green, red, and brown repeated throughout the khipu. Color banded khipus on the other hand are khipus that feature multiple sequences of identically colored pendant cords. The banded khipu in Figure 5.1 is a four-color banded khipu. In contrast to the seriated khipu, the sequence of blue pendant cords forms its own group, the green its own group, the red its own group, and finally the brown its own group. Both forms of color patterning have the capacity to format complicated cross categorization, whereby both categories and subcategories may effectively be represented by colors and color groupings (Ascher and Ascher 1997:82–83). However, identifying these signified categories has long been an open question in the khipu scholarly community (see summary of different interpretations in Chapter 1).

Recently, however, as explicated in Chapter 1, Sabine Hyland developed an empirical model of how these two color patterns could have worked together and what kinds of data they would have recorded (Hyland 2016). Hyland found unpublished testimony from a khipu expert in the community of Santiago de Anchucaya in Huarochiri Province, Peru about how color seriation worked to record labor contributions in the 1930s and 1940s (2016:491). She then compared the testimony to actual contemporaneous banded khipus produced in Anchucaya to determine how color banding would have worked as well. Hyland demonstrated that, in this post-conquest context, color seriation signified that a khipu recorded aggregate, group-level labor data and color banding signified that a khipu recorded individual-level labor data pertaining to the people within an ayllu (Hyland 2016:499, 505). These findings also seem to correspond to Urton's theory of markedness, with color seriation recording a higher hierarchical position (unmarked) than color banding (marked; Urton 2003:45-48).

While Hyland's study provides an important, historically-attested instance of color banding and seriation signification, it only refers to a single instance of khipu signification at a specific point in time after the Spanish conquest. In Chapters 3 and 4, I demonstrated that Inka khipukamayuqs replicated dicent symbols that worked in hierarchical binary pairs across the Inka empire. To test whether or not the semiotic model of paired marked/unmarked dicent symbols holds for color patterns as well, I propose several hypotheses, which I evaluate over the course of the present chapter.

Recall from Chapter 2 that each dicent symbolic legisign is composed of a rhematic symbolic legisign (predicate) and a rhematic indexical legisign (indicating the subject of the predicate). Thus, based on Hyland's study of post-conquest color patterns, we should expect color banding in extant Inka khipus to have partially been the predicate "___ records individual-level data" and color seriation to have partially been the predicate "___ records group-level data." I thus propose to assess whether or not the link to the dicent's subject correctly points to my expectations for these predicates. Does the link to the dicent's subject match my expectations of individual-level data for banded khipus and group-level data for seriated khipus?

The subjects here are the cord groupings that are indexed by the color bands themselves, which I expect to contain individual-level numerical data consistent with Hyland's findings for banded khipus in Anchucaya. The same would then also be true for seriated khipus. The subjects on seriated khipus would be the cord groupings indexed by different colors in a seriated sequence, which I would expect to record group-level numerical data consistent with Hyland's findings for seriated khipus. When a khipu repeatedly employs the same color pattern again and again (such as in Figure 5.1), it might be termed a "color banded khipu" or "color seriated khipu," which I would expect to record individual or aggregate-level data, respectively, over the whole of the khipu. Therefore, in summary, if Hyland's identified signs were used in earlier Inka khipus, I would expect to find a systematic relationship between color pattern and the order of magnitude of the numerical cord values in recorded khipus in the KDB.

Next, if Hyland's attribution of labor contribution values to the cords of seriated and banded khipus is correct (i.e. that they belonged to a labor accounting genre), I would expect a close correspondence to exist between the order of magnitude of numbers recorded on the khipu cords and those of the Inka decimal administration. Recall from Chapter 1 that the Inka administered their vast empire by organizing their imperial subjects into various, hierarchical levels of decimal sub-units, each of which had officers and responsibilities for administering the required labor tribute of their subjects. The first decimal unit at the lowest level of administrative hierarchy was the *Chunka* level, administering 10 tributaries, going up to the *Hunu* level, that administered 10,000 tributaries (Julien 1988; see Table 5.1).

Table 5.1: *Inka Decimal Organization: Decimal Units from 10 to 10,000.*

Unit name	Number of Tributaries
Hunu	10,000
Pichqa-waranka	5,000
Waranka	1,000
Pichqa-pachaka	500
Pachaka	100
Pichqa-chunka	50
Chunka	10

According to the logic laid out above, khipus with cord values in the tens-place and higher should have a higher probability of being seriated, given that this number of tributaries would have been administered as a decimal unit group and not as individual people. For instance, the 1567 Chupachu Labor Assignment documents 100 weavers per *Waranka* (1,000 total tributaries) and, interpolating from this number, 10 weavers per *Pachaka* (100 total tributaries; Julien 1988:265). Given the cotton cloth quota (from 25-50 units) for a Pachaka in the 1562 Chupachu Tribute list, the cotton cloth quota per weaver might have been expected to be two to five units per individual weaver (Levine 1987:37). If these weaving labor contributions were recorded on khipus, I would expect a khipu recording data at the Pachaka-level and above to record numerical data in the 10's place and above (i.e. each cord would have numerical values in the 25-50 range at the Pachaka-level). Such khipus that record numerical data in the 10's place and higher should be color seriated, if color seriated khipus primarily recorded group-level labor contribution data. In contrast, I would expect a khipu recording individual-level data to record numbers primarily in the 1's place (i.e. each cord would have numerical values in the two to five range for the weaving example above). Khipus that record data in the 1's place should be color banded, if color banded khipus primarily recorded individual-level labor contribution data.

Testing these hypotheses allows us to assess whether banded and/or seriated color pattern signs exclusively belonged to a labor accounting khipu genre. Because I did not know *a priori* if color banding and seriation were patterns limited to the labor accounting genre, I kept khipus from Inkawasi in the analysis at this point, even though we saw in Chapter 4 that banding and seriation-like patterns were used to signify credits and debits at the site and that the khipu magnitudes are subsequently different than expected under Hyland's model. A strong enough signal pointing to the labor accounting genre from the remaining khipus in the KDB should be visible even through this potential noise from the Inkawasi khipu archive, however.

Finally, I assess whether Inka khipukamayuqs replicated the color pattern legisigns widely across geographic space, based on extant khipu provenances for seriated and banded khipus recorded in the KDB. Note that while many of the khipus recorded in the KDB have inexact provenances, the region where they were found is often recorded and can be used to identify coarse-grained spatial effects. If I found that the signs were spatially widespread across the former Inka Empire, then they would not likely be the result of a single, localized individual or group. If instead I only identified small regions that produced the same signs, then I would interpret the identified signs as localized sign replication practices that will need to be analyzed in their own right. I would estimate a spatially-circumscribed sign production practice of this sort to have had a smaller khipukamayuq labor force than a spatially-widespread sign production practice.

Different parts of the empire were conquered by the Inka at different times over the course of their expansion from Cuzco. As such, it has been argued that the various regions were administered in diverse ways depending on the local environmental, political, and economic context (Covey 2000:120). Therefore, it would not be surprising for there to have been certain pockets of the empire that used alternative sign production practices, with divergent codes from the rest of the Inka empire. Quilter, for instance, makes the point that different geographic regions might have used different khipu conventions (2002; see also Urton and Brezine 2011, on the variable features of different khipu "archives"). As I demonstrated in Chapter 3, for example, there seems to have been uniformity in knot direction signification practices across the Inka empire, but local divergence at the site of Armatambo. Perhaps a similar semiotic divergence occurred with color banding and seriation signs.

5.2 Methods

To wrangle the data into an analysis-ready form, I used the Python Data Analysis Library (Pandas, version 0.18.0) in Python 2.7 to strip each khipu down to its pendant cord-level data (McKinney 2010; Appendix A.3). I only used pendant cord data for this analysis because assessment of color pattern in the literature on banding and seriation is based on the color of pendant cords, as opposed to top cords or subsidiary cords.

In order to test for a relationship between numerical magnitude and color pattern, I first needed to define what I meant by magnitude. Khipus often have numerical values recorded on all their cords, but in order to analyze the khipu-level relationship between magnitude and color pattern, I needed an aggregated measure of overall khipu magnitude. I decided to use the maximum pendant cord value recorded on a khipu as my proxy for magnitude. For khipus with many empty cords (which are interpreted as having the numerical value of zero), the maximum pendant cord value on a khipu allows me to focus on the cords that were in fact knotted with numerical values. This focus on cords that were knotted avoids misleading comparisons between khipus that were only partially knotted (resulting in lower overall sums and averages as a result of the zero values on empty cords) and those that were fully knotted. Furthermore, in the case of khipus that have all their cords knotted with numerical values, the largest pendant cord value on a khipu is often a summary value. Emphasizing these summary cords (when they exist) avoids deceptively deflating the overall recorded order of magnitude of a khipu by giving too much weight to smaller values (usually from 1-9) that often appear throughout even khipus with large values.

I then performed a base-10 log transformation on the maximum pendant cord value for each khipu. This transformation converted each value into the power to which the number 10 must be raised to obtain the maximum pendant cord value. So, if the maximum pendant cord value was 10, the transformed value would be 1 ($10^1 = 10$), and if the maximum pendant cord value was 1,000, the transformed value would be 3 ($10^3 = 1000$). Initially the data was extremely right skewed, meaning the vast majority of values are very small, but the tail of the distribution includes values that are orders of magnitude larger (see Figure 5.2).

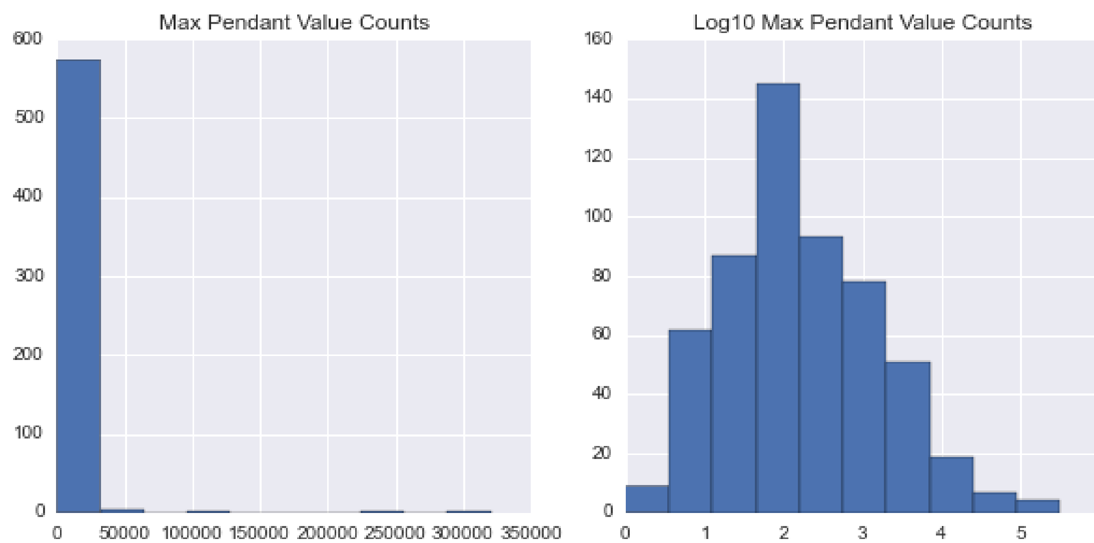


Figure 5.2: *Choosing a Magnitude Measure*

The log transformation makes interpretation of this numerical data much easier, however. For instance, an increase in maximum cord value from 1 to 100 is a much bigger shift (from individual-level data to Pachaka-level data) than is the increase between 10,000 and 10,099 (both would likely be Hunu-level data). By log transforming the data, all of our interpretations of magnitude may be conceived multiplicatively in terms of tenfold increases (paralleling the Inka decimal administration levels). For instance, a khipu whose biggest numerical value is 100 would have a magnitude of 2 and potentially be recording Pachaka level data (where 2 is the power to which 10 is taken in order to equal the maximum pendant cord value). Thus, in summary, I define khipu magnitude as the base-10 log transform of the maximum pendant cord value on a khipu.

Then, I needed to identify khipus that were seriated or banded for analysis. Pavlo Kononenko, the database administrator for the KDB from 2011-2012, wrote a series of functions that performed these operations in the statistical programming language R in 2012. I adapted the algorithms and translated them into Python 2.7 code. For banding, the function takes in all the ordered cord colors from a single khipu and calculates the percentage of cords on the khipu that occur in single-color cord groupings greater than two pendant cords per cord color. If the percentage is greater than a set threshold (default 20%), then the khipu is labeled "banded." Kononenko set this to a default of 20%, but I explored a variety of different thresholds; 20% seems too lax a definition to account for khipus that display 100% banding, like the banded Anchucaya khipus that Hyland studied or the Santa Valley khipus that Urton studied.

For seriated khipus, the function cycles through the khipu two cords at a time and assesses if the two cords are different colors. If the two cords are different colors, and the two-cord pattern matches more than the required number of matches (the default is 2), the khipu is labeled "seriated." All of the colors were recorded using folk color categories and then aggregated under a smaller set of categories using a color grouping scheme developed by Carrie Brezine for grouping colors together in a way that aggregates similar folk color categories together (see Figure 4.8 in Chapter 4). This color scheme is especially relevant when identifying color patterns because colors that might be identified as slightly different by any two researchers today may have signified the same color or color class to an Inka khipukamayuq.

Now that I had functions to identify banding and seriation, I needed to set thresholds at which to define banding and seriation from the data set. As noted above, the defaults set by Kononenko (percent of khipu that is banded: 20%, number of seriated cord groupings: 2) seemed too lax for the types of khipus I wanted to be able to identify in this analysis. Therefore, in order to decide upon a definition, I first performed a statistical power analysis. Power in this context is defined as the probability of observing a statistically significant relationship between magnitude and color pattern if there is indeed a relationship. The conventional power that researchers usually shoot for is 80%, so I adopted the same number (Cohen 1992:100). I additionally defined a statistically significant relationship as one where the odds of seriation increase by 1.5 for each unit increase in khipu magnitude. From my power analysis, I determined the sample sizes needed to achieve high statistical power and plotted these as horizontal lines superimposed on top of actual sample size counts for each set of possible threshold definitions (see Figure 5.3).

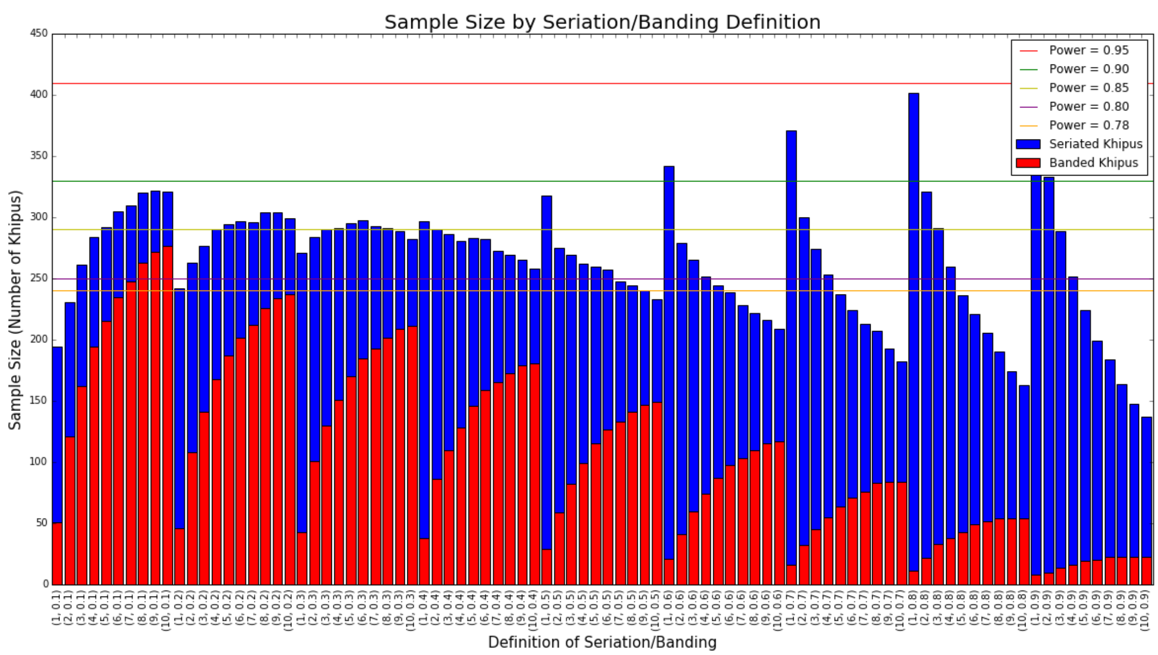


Figure 5.3: *Sample Size by Seriation/Banding Definition*

In order to calculate actual sample size counts for each threshold definition, I started by determining how many khipus were banded for the definition that 10% of a khipu was banded and how many were seriated for the definition of more than 1 matching pair of seriated cords. These combinations of banded and seriated thresholds are represented in Figure 5.3 like so: (1, 0.1). The first entry in the parentheses refers to the seriated threshold (the number of seriated cord groupings necessary to consider a khipu as being seriated), and the second entry in the parentheses refers to the banding threshold (percent of a khipu that must be banded in order to consider a khipu as being banded). Using this notation, I computed the sample sizes for banded and seriated khipus using all remaining combinations of banding and seriation thresholds (up through 100% of a khipu being banded and there being 10 matching instances of seriated cords on a khipu). I considered banded khipus to be those khipus that were solely identified as banded and not seriated and seriated khipus to be those that were solely identified as seriated and not banded.

While there were many definitions that had large enough sample sizes to get in the 80% power range, I also needed my definitions of seriation and banding to be relatively strict. A threshold of less than 20% banding, for example, is not enough to adequately compare my results with Hyland's Anchucaya khipus or Urton's Santa Valley khipus, the latter of which are 100% banded. It was also important that the selected seriated and banded khipus have a similar number of selected khipus, so that each color pattern was sufficiently represented within my statistical model. I narrowed my options down to khipus with definitions of (4, 0.5), (5, 0.5), and (6, 0.5), for being the best combinations of my above concerns (see my notes on the meaning of this notation above). For each of these definitions of seriation and banding, the power to identify a relationship between color pattern and magnitude is around 80%, they each have strict definitions for both banding and seriation, and they each feature similar numbers of seriated and banded khipus. Ultimately, for the sake of superior sample size, I went with the (4, 0.5) definition. Under this definition, when there are more than 4 matches of alternating cord colors on a khipu, this means that the khipu is seriated and when 50% of a khipu exhibits banding behavior, this means that the khipu is banded. The total sample size for this set of definitions is 269 samples (out of 626 total khipus with detailed, cord-level recordings in the database), with 101 banded khipus and 168 seriated khipus.

With all the variables now in hand, I used logistic regression implemented in Python's statsmodels library (0.6.1) to model the relationship between Banding and Seriation under the influence of magnitude. The modeled formula is as follows:

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = \beta_0 + \beta_1(Khipu\ Magnitude)$$

In contrast to ordinary linear regression, logistic regression fits a model to the log odds ratio of one categorical variable as compared to another (Agresti 2002:165-167). Logistic regression thus provides a useful way of modeling how categorical variables relate to one another via their explanatory variables (in this case, only magnitude). In order to determine whether or not there is a significant relationship between color pattern and magnitude for khipus in the KDB, I fit the logistic regression model and assessed whether or not the coefficient β_1 was statistically significant for $p<0.05$ (i.e. evidence that increasing khipu magnitude increases the odds that a khipu is seriated). If the coefficients were statistically significant, I considered this as evidence in favor of a systematic relationship between magnitude and color pattern—in short, evidence that the color pattern legisigns had been replicated according to a pre-established, highly-developed code.

Fitting the logistic regression model yields highly statistically significant results ($p<0.01$). Figure 5.4 reveals a close link between magnitude and color pattern.

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = -1.209^{*} + 0.786^{*} \times (Khipu\ Magnitude)$$

*Statistically Significant ($p < 0.01$)

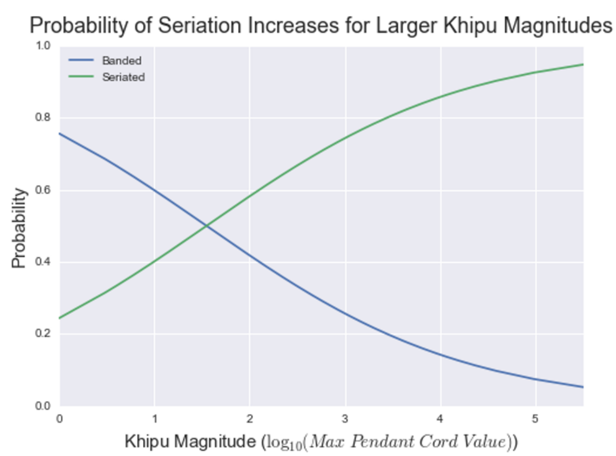


Figure 5.4: *Relationship between Magnitude and Color Pattern*

That is, Figure 5.4 illustrates that the 0th to 1st decimal orders of magnitude are dominated by Banded Khipus and magnitudes 1.5 and beyond are dominated by Seriated Khipus. This finding falls in line well with Hyland's model where each cord records labor contribution data.

Recall that, given the Inka decimal administration, I expect pendant cord values to be in the tens place at the Pachaka (100 tributaries) level of data and up to the hundreds place at the Waranka (1,000 tributaries) level, although the on-the-ground administrative specifics would no doubt often vary from this ideal (see Pärssinen 1992:404). Corroborating these expectations, my model shows a neat correspondence between pendant cord values in the tens place and greater (1.5 magnitude corresponds to a maximum pendant cord value of 30) and a higher probability of seriation. Seriated khipus, thus, appear to have recorded labor data at the Pachaka level and higher (i.e. aggregated ayllu-level data and higher). Similarly, the close association between lower magnitude values (around the order of magnitude of the tasks for an individual laborer) and banded khipus seems to indicate that banded khipus recorded data pertaining to the performance of a labor task by individual laborers. Therefore, in summary, I identified that post-conquest color banding and seriation legisigns derived from Hyland's (and colleagues') studies of post-conquest khipus were produced earlier by Inka khipukamayuqs to signify individual- and group-level data, respectively. Additionally, these color pattern signs seem to belong to a labor accounting Inka khipu genre—i.e., those recording numbers consistent with the Inka decimal organization.

To determine the geographic scale of color pattern sign replication using the KDB, I first assigned geographic coordinates to each khipu in the KDB with a labeled provenance. To assign the coordinates, I employed the GeoPy Python package (version 1.11.0; geopy.readthedocs.io), a package used to locate the geographic coordinates of cities, addresses, and landmarks (in text format) via third-party geocoders (like Google Maps or Open Street Maps). I then created spatial variables based on the coordinates of each khipu (longitude, latitude, and distance from Cuzco). In addition to longitude and latitude, I calculated the distance from Cuzco of every khipu provenance as a variable, under the hypothesis that a distance measure from the Inka capital city might have had some bearing on the level and degree of administrative oversight given to each khipukamayuq. Consideration of these spatial variables allows us to identify whether different geographic regions modified the ways in which the color banding and seriation legisigns were replicated. That is, were the legisigns only replicated in some regions and not in others? Or were they generalized, empire-wide legisigns? To answer these questions, I added the above-defined spatial variables to the color pattern logistic regression formula to determine the degree to which the identified link between magnitude and color pattern could be explained by spatial variation. Recognizing that Latitude and Longitude coordinates are inherently interconnected, I computed the coordinates' first principal component using Python's Sci-kit learn machine learning package (version 0.19.1) in order to model both longitude and latitude as a single variable (Pedregosa et al. 2011). The first principal component accounts for the greatest possible variance in the spatial coordinate data, incorporating information from both the Longitude and Latitude measurements into a single numerical value for each khipu. I called this single variable "Provenance" in the analysis below, since it is a general measure of spatial provenance. These "Provenance" and "Distance from Cuzco" spatial variables can added to the already-defined color pattern logistic regression model like so:

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = \beta_0 + \beta_1(Khipu\ Magnitude) + \beta_2(Provenance)$$

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = \beta_0 + \beta_1(Khipu\ Magnitude) + \beta_2(Distance\ From\ Cuzco)$$

Before I fit the models above, I removed the Inkawasi khipus from the analysis because we saw in Chapter 4 that seriation- and banding-like patterns on these khipus were used to signify credits and debits in a storehouse accounting context—a different recording genre (with different levels of numerical magnitude) than the labor accounting genre that seriated and banded khipus seem to have generally belonged to. Including the results of so many outliers from a single location would distort the results of the spatial analysis, so I chose to remove these khipus from consideration for this portion of the analysis.

Many recorded khipus have very little provenance data associated with them beyond a general region indicator, so clearly it is worthwhile to be cautious of any strong spatial conclusions made on the basis of the provenance data for samples across the KDB. However, for the purposes of this analysis, I assumed that the recorded region indicators (i.e. provenances) were useful, if not always absolutely accurate, and that, if nothing else, general spatial trends might be revealed if such patterns existed in the past (see resulting locations for banded and seriated khipus in Figure 5.5).

Figure 5.5: *Map of Banded (n=54) and Seriated (n=82) Khipu Locations by Recorded Provenance*

Fitting the spatial logistic regression models (see Appendix A.3), I found that "Distance from Cuzco" did not produce a statistically significant coefficient. However, the "Provenance" coefficient (that incorporates Latitude and Longitude information) was statistically significant ($p<0.05$) when I included all the khipus in the sample, indicating that there is a spatial effect determining how color pattern and magnitude relate to one another. Furthermore, banded khipus from this full set of data included uncharacteristically high magnitudes of up to 3 (a maximum pendant cord value of up to 1000), a recording magnitude that is not expected for individual-level data. However, when I only modeled khipus North of Latitude

16° S (excluding the 6 khipus from Northern Chile), there were no statistically significant results for any of the spatial variables (see Appendix A.3):

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = -0.759 + 0.570^{*} \times (Khipu\ Magnitude) + 0.232 \times (Provenance)$$

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = -1.984 + 0.575^{*} \times (Khipu\ Magnitude) + .002 \times (Distance\ From\ Cuzco)$$

$$*Statistically\ Significant\ (p < 0.05), n = 130\ (Banded = 48, Seriated = 82)$$

The color pattern semiotic code thus appears to have been dominant across labor accounting khipus, everywhere in the former Inka empire, except for Northern Chile, where banded khipus seem to have had uncharacteristically high magnitudes. But why would this one region produce signs counter to the dominant color pattern code over the rest of the Inka empire?

One reason might be that the khipus in this region come from an unusual, if not unique, sector of Tawantinsuyu, known as *Colesuyu* (Rostworowski 1986). Recall from the overview of Tawantinsuyu in Chapter 1 that the archaeology of the Colesuyu region indicates mixed Inka control of the region, with only some locales being tightly controlled by the Inka and others left to local control (Covey 2000). Perhaps in regions that were not closely overseen by Inka administrators, local khipukamayuqs used different semiotic codes from the dominant code shared by those cord-keepers who were under close surveillance by Cuzco. It might be that this region used an entirely idiosyncratic, local semiotic code, with different semantic values and ways of relating each of these signs (see the Discussion section below for a more detailed account of this argument).

5.3 Discussion

Over the course of this analysis, I have presented evidence that Inka khipukamayuqs across the Inka empire used banding and seriation color pattern signs to signify information in a similar way as khipukamayuqs in post-conquest periods. Specifically, I identified a systematic relationship between color pattern and magnitude in the khipus of the KDB and matched this relationship to the Inka decimal labor organization.

Figure 5.4 illustrates that the 0th to 1st decimal orders of magnitude are dominated by banded khipus and that magnitudes of 1.5 and above are dominated by seriated khipus. These empirical findings correlate with Hyland's model for understanding color banding and seriation in post-conquest khipus, where each cord value recorded labor units. As I noted when I defined my hypotheses to be tested at the outset of this chapter, under the Inka decimal organization, we might expect pendant cord values containing information on weavers, for instance, to contain values in the tens at the Pachaka (100 tributary) level of data and hundreds at the Waranka (1,000 tributary) level. In support of this theory, I have demonstrated a clear correspondence between a number in the tens place (a magnitude of 1.5 corresponds to maximum pendant cord value of 30) and a higher probability of seriation. Seriated khipus appear to have recorded labor data at the Pachaka-level and higher (i.e. aggregated ayllu-level data and higher). Likewise, there is a close association between banded khipus and lower magnitude, individual-level data values. Such explicit links to the Inka decimal organization numerical values support the notion that banded and seriated khipu signs were used primarily in a labor accounting khipu genre to signify different levels of aggregation in the labor accounting process.

If seriated khipus recorded any level of labor aggregation in the Pachaka level of administration and higher, though, how would aggregation from one seriated khipu to another have conceptually worked? For instance, how would the values from a Pachaka level khipu have been aggregated into the values of a Waranka level khipu? The color seriated khipus from Puruchuco—an Inka administrative center for labor accounting on the south bank of the Rimac River—provide an excellent illustration of how this process of aggregation across seriated khipus might have worked more generally (see Figure 5.6).

Urton and Brezine found that the Puruchuco khipukamayuqs used both spacing along a khipu's primary cord and color to organize their color seriated sequences and conceptualize

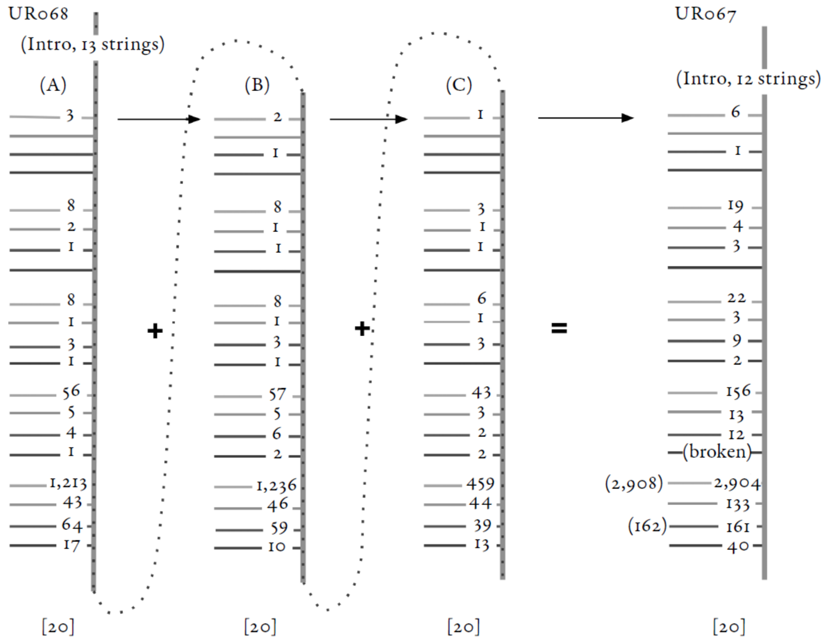


Figure 5.6: *Numerical and color correlations between khipus UR068 and UR067 (From Urton and Brezine 2007:369)*

the aggregation of numbers across seriated khipus (2007:367–369). In UR068, for instance, each sequence of color seriated cords (20-cord sequences: lettered A, B, and C in Figure 5.6) was separated from the others by a space along the primary cord. Within each seriated sequence of cords, the color and relative position of an individual cord seems to have been conceptualized as a discrete unit. It was only across these logical units that the Puruchuco khipukamayuqs calculated aggregate values for these seriated khipus. For instance, in the case of UR068 (Figure 5.6), the fifth cord in the first seriated sequence (A) is the number 8 (colored white), the fifth cord in the second seriated sequence (B) is the number 8 (colored white), and the fifth cord in third seriated sequence (C) is the number 3 (colored white). Adding the cords together, the khipukamayuq calculated the number 19 on a cord colored white at the exact same position (fifth) in a color seriated sequence on a different khipu: UR067.

If we interpret the Puruchuco khipus as labor documents, we might speculate that each color and/or cord position in a khipu's seriated sequence was an aggregate account of a particular group of people's performance of a common labor commitment. Khipus that recorded the performance of separate Pachaka labor units on a series of tasks could be aggregated using a similar conceptual logic as seen in Figure 5.6. For example, if each Pachaka recorded an identically-coded seriated sequence of tasks they completed, a Waranka-level administrator would simply add all of these Pachaka-level labor statistics together by color and cord position (just as seriated sequences A-C were added together in Khipu UR068) to record summary statistics at the Waranka level of decimal organization. The same aggregative process could then be repeated to record Hunu-level labor statistics from multiple Waranka-level khipus.

In addition to the correlation between color pattern and aggregation level that I identified in the khipus of the KDB, I found the banding and seriation color pattern signs to largely be geographically constant throughout the Inka empire. However, khipus from the Northern Chilean coast were extreme outliers. Banded khipus from this region include uncharacteristically high magnitudes of up to 3 (indicating a maximum pendant cord value as large as 1,000). Why might this be? When I dropped these six Chilean khipus from the analysis, I found that the "Provenance" geographic variable that I defined (which takes into account both longitude and latitude) had no statistically significant influence on the use of color pattern signs for the remaining khipus in the analysis. In other words, everywhere else in the Inka empire, the relationship between color pattern and magnitude was constant—there was no clear difference across geographic regions.

As hinted at earlier, the six divergent khipus all come from the Northern Chilean coast, a region that was known as *Colesuyu* by the Inka. Interestingly, as I mentioned in Chapter 1, Colesuyu was even a bit of an aberration for the Inka. Recall that the Inka called their own empire *Tawantinsuyu*, or "the four parts together" in Quechua, where each "part" of the empire was called a *suyu*. They saw their empire as being composed of four regions radiating out from their capital city of Cuzco: *Cuntisuyu* (the southern coast of modern Peru, west of Cuzco), *Chinchaysuyu* (the northern portion of the empire), *Antisuyu* (the eastern portion of the empire), and *Collasuyu* (the southern portion of the empire, extending through the modern Bolivian altiplano as well as sections of Chile and Argentina). The term Colesuyu, on the other hand seems to have been an indigenous, non-Inka geographical concept used to describe the region that is now northern Chile, awkwardly imposed upon the standard Inka quadripartite division of space (Bouysse-Cassagne 1986:218; Rostworowski 1986:128).

In addition to this conceptual divergence from Inka spatial terminology norms, the archaeology of Colesuyu indicates a mixed Inka control of the region, with only some locales being tightly controlled by the Inkas and others left to local control (Covey 2000). Despite Inka supervision, for instance, there is evidence of several distinct local ethnic groups pursuing their own economic modes (e.g. fishing for some groups, as opposed to agricultural cultivation for other groups) (Rostworowski 1986:132; Hidalgo and Focacci 1986).

Furthermore, because of this patchwork of geopolitical identities, the Inka appear not to have possessed (or even pursued) hegemonic control over the Colesuyu region (Rostworowski 1986:127). Instead, they focused on maintaining their southern roads in the region through a series of *tambos* (way-stations) that stretched all the way down what is today the north coast of Chile to form a connection with important copper and turquoise mines to the South (Rivera 1991:38-39). As a result, in other areas of life, including khipu record keeping, local codes proliferated over the standardized code of the Inka empire.

Contrast the above situation in Colesuyu with the situation pertaining to the khipus found at Inkawasi. The latter, as we have seen in Chapters 3 and 4, was an Inka-run military garrison on the southern coast of Peru, which would have been closely overseen by administrators from the capital. Furthermore, Inkawasi was explicitly designed by the Inka to be an architectural manifestation of the capital city of Cuzco (Hyslop 1985). In this Inka-run military garrison and physical manifestation of the center of the empire, we would expect that the legisign conventions would have been reproduced according to the standard state semiotic codes.

In the case of the Colesuyu khipus, though, I argue that local codes prevailed over the hegemonic Inka khipu codes. We would expect khipus from tightly controlled/monitored regions to have replicated legisigns from codified Inka standards. On the other hand, in regions that were not controlled tightly by the Inka, we might expect to see local signification different from the broader, strictly codified set of Inka semiotic practices. Thus, I interpret my findings about the relationship between color pattern and magnitude to mean that color banding and color seriation were conventionalized Inka signification practices that held within the regions that were under direct Inka control. This same interpretation about conventionality is likely to have been true for other khipu signs as well—legisigns were only conventionalized across geographic regions where the Inka exerted direct control. Where Inka control was in question, state monitoring of codified Inka legisign replication may have been much more lax.

Thus far, I have demonstrated a systematic relationship between color pattern and aggregation level for the Inka khipus in the KDB. However, as of yet, I have not dealt with how this relationship would have functioned in the overall process of Inka color pattern signification and interpretation. In short, how did these elements function as signs? If we hope to understand the relationship between color pattern and aggregation level as a signifying practice and not just as a statistical regularity, it is essential that we understand specifically how color banding and color seriating signs would have functioned for khipukamayuqs.

First, we might interpret the banding and seriation khipu color patterns as legisigns. I have empirically demonstrated that color banding and seriation were widespread Inka signification practices for recording what appears to be labor data (a link between sign vehicle and object). Thus, they do not appear to have acted as a purely mnemonic aid to an individual khipukamayuq wishing to format categories. Instead, color banding and seriation constituted a highly standardized, conventionalized set of practices that could have been referenced by anyone formally trained to interpret khipus. As such, each individual instance of color banding and seriation on a khipu was a replica of the color pattern legisigns.

Additionally, the primary relationship between color patterns and the objects they signify seems to have been a symbolic one. The relationship between color pattern and aggregation could theoretically have been reversed given that both color categories have an equally high capacity for cross categorization (see Ascher and Ascher 1997:132–133). For instance, color banding could theoretically have been used to signify that a khipu contained aggregated data, and color seriation could have been used to signify that a khipu contained individual-level data. However, as I empirically demonstrated over the course of my analysis, color seriated khipus seem to have been conventionally associated with aggregated data and color banded khipus seem to have been conventionally associated with individual-level data.

Finally, I argue that color banding and seriation on a khipu were dicent symbolic legisigns—conventional signs which establish a correlation with their object and provide information about it in a propositional fashion. In the example of khipu banding and seriation, color pattern is a symbolic predicate, in the sense that it signifies the possibility of individual- or aggregate-level data (i.e. the predicates "records individual-level data" or "records aggregate-level data", without their corresponding subjects). The different color sequences in each color pattern (whether the individual bands of a single color or groups of seriated cords) also point to particular cord groupings, providing a propositional connection between the symbolic predicate and the subject of that predicate—the cord groupings themselves. Thus, a same-color cord sequence within a color banded set would have been interpreted by a trained khipukamayuq as recording a series of individual-level labor contributions, while cords within a color seriated sequence would have been interpreted as recording an aggregate-level labor contribution. By extension, when a khipu repeatedly featured the same color pattern again and again, which I have termed a "color banded khipu" or "color seriated khipu," it would have been interpreted as recording individual- or aggregate-level labor contribution data, respectively, over the whole of the khipu.

5.4 Conclusion

Considering khipukamayuqs' use of conventionalized knot direction and cord color signs (Chapters 3 and 4), it seems that color banding and seriation signs belonged to one set of marked/unmarked dicent symbolic legisigns within a much larger set of signs available to Inka khipukamayuqs as a standard signification vocabulary. Color banded signs were marked in relation to color seriated signs, where banding signified individual-level labor contribution data and seriation signified aggregate-level labor contribution data. However, this conventionalized relationship was not necessarily universal in all geographic regions of the empire. In regions dominated by the Inka state, state-mandated semiotic codes also seem to have dominated. In these Inka-dominant regions, the relationship between color banding and seriation described above seems to have been consistently maintained. However, in regions with lesser Inka control, like the Colesuyu region, color banding and seriation and were used in different ways, according to local codes.

In summary, the banding and seriation color pattern signs seem to have been produced as dicent symbolic legisigns in hierarchical binary pairs across a broad geographic scale within the labor-accounting genre. Furthermore, this chapter provides evidence that khipu sign conventions did in fact vary by political geography and that signs could be circumscribed by the particular genre they belonged to.

Chapter 6

Outlining a Grammar of Inka Khipu Signs

The *Oxford English Dictionary* defines the word *grammar* as follows:

> That department of the study of a language which deals with its inflectional forms or other means of indicating the relations of words in the sentence, and with the rules for employing these in accordance with established usage; usually including also the department which deals with the phonetic system of the language and the principles of its representation in writing. (2018)

Based on my findings from individual khipu signs in the previous chapters, I argue that we now have the components necessary to begin to sketch such a grammar of Inka khipu signs—an exposition of how khipu signs generally worked for the Inka. Over the course of this final chapter, I will start the process of constructing this grammar. As more non-numerical signs are systematically identified and deciphered in future studies of Inka khipus, additional detail can be added to my initial exposition.

6.1 The Principles of Representation using Inka Khipu Signs

In Chapters 3-5, I explicitly dealt with the second portion of the above definition of grammar: the question of how khipu signs were used to represent non-numerical information. While Inka khipukamayuqs do not seem to have employed phonetic signs, they signified non-numerical information using an elaborate, conventionalized system of dicent symbolic legisigns.

For instance, knot direction signs seem to have been replicated throughout the Inka khipus in the KDB. That is, knot direction signs appear to have been conventionalized across various genres and in different geographical locales. Specifically, S- and Z-knots were used as dicent symbols to represent marked and unmarked categories respectively. I argued in Chapter 3 that these knot direction signs were used as grammatical markers in signifying numbers, directly positing a marked/unmarked status for each numerical knot according to its numerical status in Quechua.

Recall that, in Peirce's system, dicent symbolic legisigns are composed of a rhematic symbolic legisign (predicate) and a rhematic indexical legisign (indicating the subject of the predicate). In the case of knot direction, each knot's direction was a predicate signifying whether a knot was grammatically the possessor (unmarked) or the possessed (marked). This allowed khipukamayuqs to express compound numbers like "13," which is spoken in Quechua as "ten, possessor of three," where the higher decimal place is unmarked (and thus inclusive of the lower decimal place). Furthermore, knot direction physically indicated the subject of this predicate by being attached to the knot that it modified.

However, while there is evidence of this type of knot direction legisign replication at an aggregate level across the Inka khipus in the KDB, the Armatambo khipu archive hints that there may have been alternative codes used for other sorts of khipus. Perhaps alternative codes, like that at Armatambo, derive from use-cases in different genres under a single hegemonic Inka khipu code or possibly alternative types of recording that specifically reflect the social groups that produced them. The Armatambo khipus were found in an indigenous-style burial context (with non-Inka grave goods), so it is possible that the khipus recorded something that differed from the official Inka administrative recordings at the site.

Similarly, in Chapter 4, I found that the colors on wrapped sticks excavated at Inkawasi were used as codes for marked/unmarked pairs of cord color dicent symbols on the khipus at the site. Additionally, analysis of the KDB demonstrates that the various combinations of these colors were present throughout the KDB (and, thus, throughout the Inka empire). Furthermore, it also seems likely that such color combinations were conventionalized as marked/unmarked pairs widely across the KDB. I additionally demonstrated in a close study of Inkawasi khipus UR267A and UR255 how color binaries were used as marked/unmarked pairs to signify arithmetic actions. Finally, I suggested how similar color binaries could have been generally used by Inka khipukamayuqs across the Inka empire to signify other actions and concepts associated with cords. As with knot direction signs, color predicated each cord with a value—in this case, "___ is added," "___ is subtracted," and so on (referring to the numerical value recorded on the cord). Additionally, because the colors were applied to the cords themselves, they indicate that the subject of the predicate is the cord itself (and, by extension, the numerical value on the cord). Therefore, cord colors also were used as dicent symbolic legisigns.

In conjunction with marked/unmarked knot direction signs and cord color pairings, I found that color banding and seriation were an additional set of dicent symbolic legisigns available to Inka khipukamayuqs. These color pattern legisigns also seem to have existed in a marked/unmarked pair. Color seriated khipus recorded group-level data and thus were, by definition, more inclusive than color banded khipus that recorded only individual-level data. Thus, color seriated khipus signified an unmarked category and color banded khipus signified a marked category. I argue that these color pattern signs also worked as dicent symbols. The color banding pattern seems to have predicated the value "___ records individual-level data" and the color seriation pattern seems to have predicated the value "___ records group-level data." The subjects of banded khipus—the single-color cord groupings—were indexed by the color bands and the subjects of seriated khipus—the multi-colored, seriated cord groups—were indexed by each seriated sequence of colors.

Additionally, the consistent use of the color banding and seriation sign-pairing across a wide geographic region supports the notion that signs within a given genre (in this case, the labor-accounting genre) were widely conventionalized within that genre, but not necessarily outside of it. The key to this conventionalized sign production seems to have been the degree of dominance of the Inka empire in the region (and the dominance of its semiotic codes). The khipus found in Colesuyu, for instance, used color banding and seriation in different ways than the rest of the empire, which was likely a result of patchy Inka control over the region.

Therefore, based on my findings across multiple major sign vehicle classes, I argue that non-numerical Inka khipu signs generally functioned as dicent symbolic legisigns that were then replicated widely throughout the Inka empire. However, my findings also suggest that the scale of legisign replication was dependent on genre and political geography. For instance, non-numerical sign production seems to have been highly circumscribed by the particular genre the signs belonged to. As I noted above, color banding and seriation seem to have been limited to the labor accounting genre. Additionally, recall that the Armatambo khipus display different knot direction patterns than those of khipus anywhere else in the KDB. As I discussed in Chapter 3, this divergence was perhaps a result of those khipus belonging to a different genre (perhaps an indigenous genre, specific to the mortuary context in which the khipus were found) than khipus from other known administrative contexts such as Inkawasi, Puruchuco, and Pachacamac.

Furthermore, the geographical scale at which the dicent symbols were replicated depended on how tightly the Inka controlled the region in which they were produced. Areas under direct Inka control used state-mandated conventions more readily than those that were not under direct control. As I mentioned above, the khipus found in Colesuyu (a region spanning part of the coastal region of present-day southern Peru and northern Chile that was only loosely controlled by the Inka), for instance, used color banding and seriation in different ways than the rest of the Inka empire. This finding suggests that khipu semiotic codes were more rigorously enforced in Inka power centers and highlights the importance of understanding the production context of Inka khipu signs in order to interpret what they mean.

If the Inka enforced all of their khipu semiotic codes with physical models like the wrapped sticks at Inkawasi, we should expect there to have been political geographic variability across other non-numerical sign classes as well. The wrapped sticks would have been a rather fragile way to maintain an imperial semiotic color code in the midst of competing local codes. That being said, there were likely copies of the wrapped sticks around the empire that could have been called upon if any wrapped sticks were lost or broken in a directly-controlled administrative center. Areas like Colesuyu with indirect Inka control, though, could have easily spawned their own local codes in the absence of such codified models (and/or direct oversight) from Cuzco. Thus, one central takeaway for the interpretation of Inka khipus is the importance of considering the political geography of each khipu's provenance. While not all of the khipus in the KDB have documented archaeological provenances, the approximate provenance data that is available for these khipus could still be helpful in identifying whether they were likely to have been produced under dominant Inka semiotic codes or not. While Inka khipus seem to have been overwhelmingly conventionalized, I have demonstrated that there were geographic pockets where subaltern codes also seem to have been active. Therefore, the decipherment and interpretation of any given khipu depends on having contextual knowledge about the genre the khipu belonged to, as well as the khipu's provenance.

At a general, comparative level, my findings suggest that Inka khipus likely would not have signified information using the sorts of phonetic signs other civilizations employed in their writing systems. Rather, Inka khipus predicated non-numerical information using marked/unmarked pairs of dicent symbolic legisigns. If we accept Boone's definition of writing presented in Chapter 1, however, the Inka khipu system of representation should still be considered a writing system. Recall that Boone suggested that writing is the practice of recording information "by means of graphic or tactile marks that are made on or in a permanent or semipermanent substance" that are conventionally understood within a community to signify information (2011:379). Inka khipukamayuqs employed tactile marks–knots and colors, to name a few–in a semipermanent substance–fiber and cords. Furthermore, as we have discussed above, these marks were conventionally used and understood to signify common concepts across Tawantinsuyu in a way that is functionally equivalent to other writing systems around the world.

While Inka khipu signs generally do not seem to have had phonetic meanings, this should not dissuade future researchers from considering phonology in future decipherment efforts. Peirce, for instance, argues that sign vehicles can be related in multiple ways to their objects (i.e. both symbolically and iconically; see 1955:115). It is thus possible that one avenue for deciphering future cord color pairings is to consider the iconic characteristics of the colors, such as their sounds in indigenous Andean languages or the images they evoke. Such iconic relationships may have informed the symbolic relationship of a color with a particular concept.

For instance, in the post-conquest Collata khipus, Hyland found that cord colors phonetically signified the Quechua names for the colors (2017). Using the rebus principle, sequences of differently colored cords on the khipus were then used to phonetically record ayllu names. The use of wrapped sticks and marked/unmarked color pairs at Inkawasi (and likely across the KDB khipus) does not seem to suggest that the Inka employed a widespread, predominantly phonetic cord color system like Hyland found from post-conquest times. However, it is possible that the phonetic characteristics of Inka color signs hinted at the conceptual categories a particular color pair represented. For instance, a khipukamayuq could have recorded concepts via colors that phonetically sounded similar to the concept name. Similarly, a khipukamayuq could have recorded concepts via colors that visually represented something similar to the concept. Thus, while the primary relationship between sign-vehicle and object would have been symbolic and arbitrary (as between the color white and the arithmetic action of "addition"), there could still have been secondary iconic characteristics that will prove useful for further decipherment.

6.2 Signifying Relations Between Signs in Inka Khipus

Now, let us address the rest of the definition of grammar quoted at the outset of this chapter. Specifically, I seek to answer the question of how Inka khipukamayuqs signified relationships between signs (i.e. as words are related to one another in a sentence in a linguistic grammar). I demonstrated in Chapters 3-5 how each dicent symbol on a khipu belonged to (or was derived from) a marked/unmarked binary sign pair. Furthermore, I identified binary sign pairs that operated on different nested levels of meaning: at the knot level, the cord level, the cord grouping level, or the khipu-level as a whole. This sophisticated system of signs allowed Inka khipukamayuqs to produce meaning that was true for the entire khipu, or specific to a group of cords, a single cord, and/or a single knot. In the remainder of this section, I will elaborate on how the system of nested marked/unmarked sign pairs made it possible for khipukamayuqs to denote relationships between signs, such as possession, numerical level, and temporality.

Khipu-level signs signified at the highest level of nested meaning on a khipu. Khipu-level signs could thus act as a contextual background for the other signs nested beneath them. The contextual information they signified would have been relevant to every cord grouping on the khipu, every cord, and every knot. We saw two empirical examples of khipu-level signs in the preceding chapters. In Chapter 5, we saw that khipus could be entirely composed of color banding or seriation patterns, and thus, be called color banded or seriated khipus—recording either individual or aggregate level labor contribution data throughout the entire khipu. Additionally, recall from Chapter 4 that khipukamayuqs at Inkawasi used either White or Amber Brown (W or AB) in khipus UR267A and UR255 as the color that would signify addition, the unmarked category in the addition/subtraction conceptual pairing used to signify the arithmetic operations in these khipus. Importantly, this choice of W or AB as the unmarked color for the khipu, further indicated whether the khipu as a whole recorded "net credit" arithmetic operations, or "net debit" arithmetic operations. I will discuss both of these khipu-level signs in turn.

Color banding and seriation khipu-level signs indicated that each cord grouping recorded labor records for either individual-level or group-level data respectively. In this sense, khipu-level color patterns formed a "title" or "preface" for a khipu that provided the interpreter with relevant information for understanding every banded or seriated cord grouping, cord, and knot within the khipu. These khipu-level color patterns were formed by combining many cord grouping color patterns together, forming a consistent pattern in the khipu that could be interpreted without referring to any of the individual cord groupings or cords. The resulting khipu-level signs thus gave context to all other signs on the khipu as operating within the genre of labor accounting at either the individual or aggregate level, depending on whether the khipu was color banded or seriated, respectively.

Similarly, at Inkawasi, khipus UR255 and UR267A each feature a dominant, unmarked color throughout the khipu—AB or W—that, to the trained eye, would have revealed the type of arithmetic operations being performed across the khipu as a whole. I will refer to khipus that use AB as their unmarked color as base-AB, and those that use W as their unmarked color as base-W. The base-AB or base-W khipus were likely formed by drawing on color pairings from a wrapped stick at the site of Inkawasi, with the unmarked color in one pairing being W (its marked pair being AB) and the unmarked color in another pairing being AB (its marked pair being Medium Brown, or MB). This choice would have been necessary before any cords were added to the khipu, so as to ensure a correct (and consistent) cord color scheme was used to signify the arithmetic operations on the khipu. Otherwise, there could be confusion about the exact arithmetic operations that were performed on the khipu.

Recall from Chapter 4, that one result of choosing a base, unmarked color was that this color—either AB or W—would dominate the khipu and subsume other marked colors. As such, the base color would be extremely visible at the khipu-level. The base-W khipu signified that the khipu as a whole recorded arithmetic operations necessary to calculate net credit for each storehouse transaction and the base-AB on the other khipu signified that the khipu recorded arithmetic operations necessary to calculate net debit. Note that this color choice follows the logic of Chapter 4, where darker colors tend to signify marked categories and lighter colors tend to signify unmarked categories. Furthermore, the use of AB and W at the khipu-level mirrored the use of the color in khipu UR267A at the cord level, where AB cords designated the subtractive arithmetic action and W cords signified the additive arithmetic action. The choice of base unmarked colors for each khipu's arithmetic operation, had the potential to change the entire color scheme of each khipu and would have made it possible for a khipukamayuq to see at a distance which types of operations a khipu recorded. In so doing, these base colors provided contextual information about the underlying arithmetic operations common throughout an entire khipu, also emphasizing the fundamentally different calculations being performed between khipus with different base colors. In the case of UR255 and UR276A, at a khipu-level, a khipukamayuq could identify which khipu was used for recording net debit operations and which one was used for recording net credit operations.

Additionally, these khipu-level base color signs would have had an effect on the interpretation of all the signs nested beneath them—whether at the cord group-, cord-, or knot-level. For instance, on a net debit khipu, the khipukamayuq would know to designate addition with AB and subtraction with MB on the cord level. Additionally, in interpreting the results of these arithmetic actions, the khipukamayuq would know to interpret all numerical knot data as contributing to net debit resulting values, as opposed to net credit resulting values. Khipu-level color signs, thus, seem to have been used to distinguish one khipu from another and provide contextual information important for producing and interpreting the rest of the signs on a khipu.

Other probable khipu-level signs that remain unexamined are the twist, fiber, and color scheme of the primary cord, as well as the colors and designs on the end bundle, or *cayte*, that is featured on many khipus. Primary cords often display brilliant color schemes and ornate end bundles, so it seems likely that they conveyed some level of information. Furthermore, given that many of these primary cord features would have had to be produced prior to attaching any pendant cords, it seems reasonable to assume that primary cords would have signified information relevant to understanding khipu signs that were nested beneath them. However, up to this point, Inka khipu primary cords remain largely unstudied. Further work must be done to identify if (and subsequently, how) primary cords and cayte bundles supplemented khipu-level color signs to provide additional contextual information about khipus as a whole.

Below the khipu-level signs, cord groupings provided additional granularity and capacity for relating signs to one another in a variety of ways. In my studies, for instance, I identified color banded and seriated cord grouping signs. I argued in Chapter 5 that each grouping contained data about the labor tasks of groups and/or individuals. In post-conquest times, Hyland found that each seriated cord grouping was related to a particular task and each color within the cord grouping corresponded to an ayllu group's contribution toward the completion of that task (2016:499). Each cord grouping in a color banded khipu (a band of a single color) seems to have corresponded to a single individual and the cords within that band seem to have corresponded to their individual contribution toward their ayllu's labor tasks (Hyland 2016:505). Therefore, each cord grouping designated by a color pattern was also a contextual sign for the cords under its purview—either grouping together ayllu labor contributions toward a task, or grouping together an individual's contributions toward a set of tasks.

In Inka khipus, color patterns at the cord group level were also likely used to designate how cord groups as well as individual cords related to one another. For example, we might expect color seriated cord groupings to have referred to a particular labor task and individual colors designated by the seriated cord grouping to have referred to the contribution of particular labor units within the Inka decimal organization. A seriated cord grouping could have predicated each cord's numerical value with the phrase "was contributed toward completing task W." Assuming the seriated khipu recorded Pachaka (100-person labor unit) labor contributions, the Pachaka that made the contribution would have been indicated by the cord color in the seriated sequence. Likewise, color banded cord groups could have predicated each nested cord's numerical value with the phrase "was the labor contribution of individual α," where the specific color of the color band indicated who the individual was (α) and each cord within the band indicated that individual's contribution towards a particular task. Medrano and Urton, for instance, suggest that the specific colors of the color bands in the post-conquest Santa Valley khipus could have signified the first names of the individuals whose contributions were recorded in the khipus (2018:19). In support of this argument, they found that there were 32 unique cord colors/color combinations represented in the khipus and 30 unique first names recorded in the Spanish colonial document that matches the recordings on the khipus. While the numbers of unique colors and names do not perfectly match (which is possibly a result of on-the-ground accounting "noise"), the numerical similarity between the two is at least suggestive of a relationship between individual identities and cord colors/color combinations.

While it is unclear exactly how the color seriated cord groupings in the Anchucaya khipus were ordered along the khipu primary cord, Hyland argues that the spatial order of the bands in the color banded khipus would have followed the order of membership into the moiety (with the most senior members coming first) just as members are ordered in modern notebooks performing the same function (2016:501). Thus, at least for the banded khipus, the cord groupings in the Anchucaya labor khipus seem to have additionally encoded temporal, age-rank relationships between the cord group-level signs based on their position along the primary cord.

For a more general example of post-conquest cord group ordering, consider the 19th century sheep herder's khipu that Hyland studied from the Cutusuma hacienda in Bolivia. On the khipu, the cord grouping that recorded female sheep always occurred before the cord grouping that recorded male sheep (Hyland 2014). This consistent ordering reflects a ranking of the animals based on their markedness characteristics. Females have the capacity to reproduce, so they were seen as the unmarked category in comparison to the male sheep. Thus, in both of these post-conquest contexts (Anchucaya and Cutusuma), cord groups signifying higher ranked categories generally seem to have been spatially ordered before cord groups signifying lower ranked categories.

We might expect to see similar relationships between groupings of Inka khipu cord groupings, where banded and seriated cord groupings might have been spatially ordered according to specific age-ranks (in the case of banded khipus), or task-ranks (in the case of seriated khipus). While it is still unknown how the Inka would have designated the order in which a khipu should be read, their common use of cayte bundles or end knots suggests that these features might have indicated the "start" of these khipus. Hyland, for instance, reported that caytes indicated the start (and the subject matter) of the khipus at Anchucaya (2016:495). Future studies of relationships between cords should investigate these cayte features in more depth. However, for the purposes of the figures in this chapter, I will assume that the order of interpretation for these hypothetical khipus was from left to right.

If sequences of Inka khipu cord groupings can also be interpreted as being temporally or hierarchically related to one another, we might interpret a color-banded Inka khipu cord as follows (see the first cord from the left in Figure 6.1 for reference): "5 [was] the labor contribution of the most senior individual, α, [toward completing] task W."

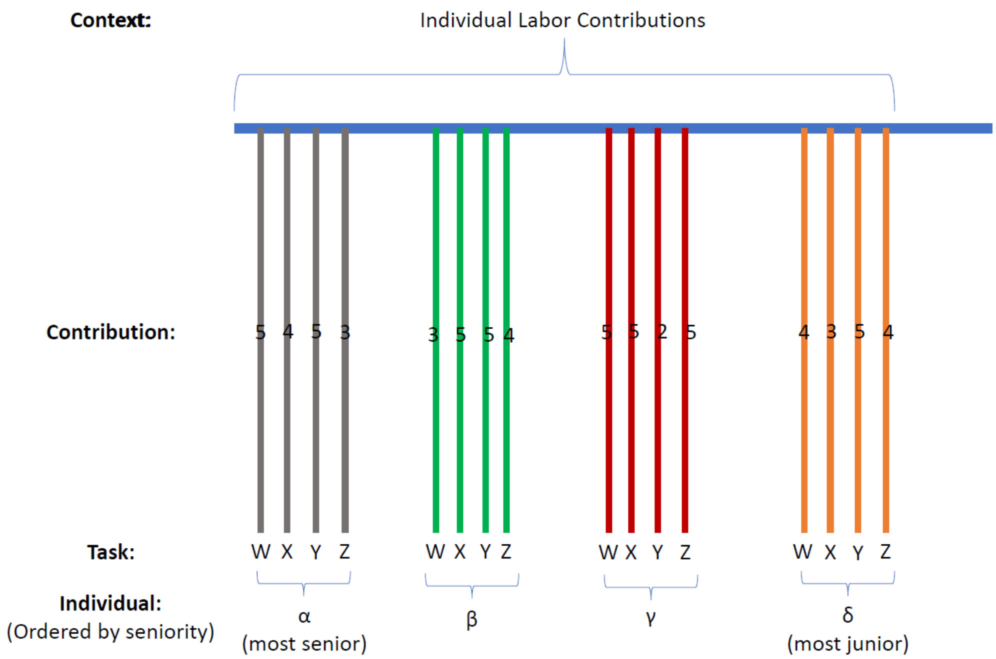


Figure 6.1: *Interpreting the Relationships Between Signs on a Banded Khipu (Hypothetical)*

In this hypothetical reconstruction, the khipu-level color pattern predicates the entire khipu with the contextual information that the entire khipu is about individual-level labor contributions. The grey color banded group predicates the first group of cords with the information that each cord "was the labor contribution of individual α", who we know "was the most senior individual" because α's banded cord grouping appears before all of the others (β, γ, and δ). Individuals are indicated by the exact color used for the color band. Finally, each cord is denoted as recording a contribution "towards community labor tasks" W, X, Y, and Z based on the order in which a cord appears in each color band. As such, each numerical value on a cord records the number of units of labor relevant to the particular task at hand (e.g. the production of 5 textiles in the above example, if task W is a textile production task). Similarly, for the contribution of Individual δ towards task Z, a khipukamayuq might interpret the khipu in Figure 6.1 as saying "4 [was] the labor contribution of the youngest individual, δ, [toward completing] task Z."

Likely, cord groupings were similarly ordered along a primary cord in other undiscovered genres of khipus as well. Note for instance, that even when color patterns do not play a prominent role on a khipu, cords can be grouped together by their relative spacing along the primary cord. These spaces between cords presumably worked much like spaces and tabs in a phonetic writing system, signifying grammatical distinctions between groups of cord signs. Further work must be done to identify how these other sorts of cord groupings generally related to one another on Inka khipus, as well as if there is any other evidence of the importance of the relative order of these groupings.

Within cord groupings, the spatial order of individual cords along the primary cord was also likely widely important, either temporally or according to other principles of hierarchical rank. In a burial chamber built into a cliff face overlooking Laguna de los Cóndores in northeastern Peru, for instance, archaeologists found what appears to be a calendrical khipu (along with 31 other khipus), called UR6 in the KDB. Urton found that the number of cords (contained within 24 cord-groupings of around 30 cords each) on khipu UR6 (composed of a total of 730 cords) was consistent with those of two calendar years (Urton 2001). Furthermore, the sum of all of the values on the cords was equal to 3005—very close to three Waranka units (1000-person labor units in the Inka decimal organization). Urton interprets this correspondence as indicating that the khipu was a labor census, recording the number of corvée laborers allocated on any given day over the course of the two-year period (Urton 2001). Thus, each cord would have been temporally ordered from the start to the finish of the two-year period.

Similarly, in Chapter 4, I demonstrated that the arithmetic actions in UR267A and UR255 were signified in the order in which the calculation was meant to be made. Khipukamayuqs used dark and light colors to signify the arithmetic action associated with a particular cord, culminating each time in a color combination "result" cord that synthesized each grouping of arithmetic operations into a single number. Each "result" cord could not be computed until its corresponding sequence of addition and subtraction arithmetic actions was completed. Thus, the "result" cords were placed at the end of each sequence of arithmetic actions. In this way, the khipukamayuqs enforced the temporal sequence in which each set of arithmetic actions was meant to be interpreted.

Cord-level dicent symbols had the entire cord as their subject, so all the knots recorded on a cord took on that cord's predicated value. In Chapter 4, I demonstrated that cord color was used as a dicent symbol, drawn from families of complementary color pairs. In the case of Inkawasi UR267A, the action of addition was applied to the value 106 on the first cord, subtraction to the value 15 on the second cord, and the action of synthesizing the two operations applied to the value 91 on the third cord. Cord color was thus used to predicate each number on a khipu cord with a specific arithmetic action to be performed. For a white cord in the same color scheme as UR267A at Inkawasi, with the number 90 on it (see the first cord from the left in Figure 6.2), we might interpret it as the phrase "90 [was] added,"

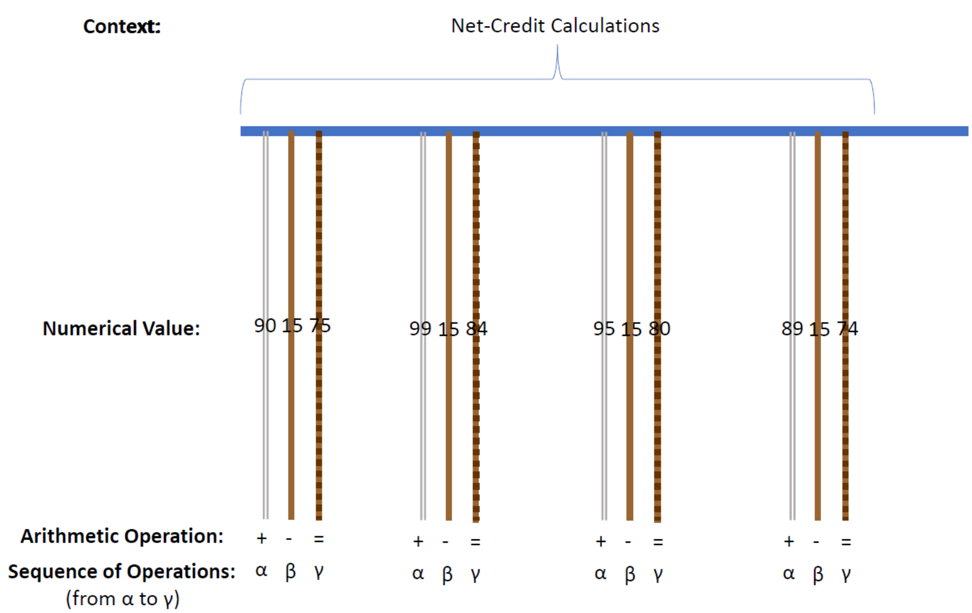


Figure 6.2: *Interpreting the Relationships Between Signs on a Khipu Recording Net Credit Calculations (Hypothetical)*

in a sequence of actions, from α to γ, where "15 [was subsequently] subtracted," and "75 [was subsequently the] resulting net credit." Recall that because white was used as the color to designate addition in this khipu (which I termed "base-W" when I discussed khipu-level signs), every arithmetic sequence recorded on the khipu would have been predicated by the phrase "is a net credit calculation," which I have included in the phrasing for the "result" cord in my interpretation of such arithmetic sequences.

Likely, similar sequences of actions would have been signified by individual cord order on khipus from a variety of genres around the empire. Complicated narratives, with actions more expressive than the arithmetic operations of a storehouse, could similarly have been represented using these same semiotic techniques. For instance, a khipukamayuq could have signified a series of actions using different cord colors (and cord color combinations), where the order in which the cords were attached onto the primary cord signified the order in which different actions occurred. For instance, as I mentioned in Chapter 4, a vast amount of information could have been signified in this way, substituting arithmetic verb pairings for unmarked/marked word pairings like "given" and "taken," or "fought" and "protected."

However, the spatial order of cord-level signs need not only refer to temporal relationships between the signs. Recall that the spatial order in which cords are attached onto a primary cord has also been shown in post-conquest times to have signified differences in rank between different categories (e.g. between female and male sheep). We might expect other conceptual categories, such as labor tasks or names of labor units to have similarly been ranked according to their perceived markedness relationships. These rankings would not have been limited to spatial cord group order. Rather, such rankings could also be made within cord groups via the spatial order of individual cords. For instance, assuming color bands indicated individual identities and the cords within the bands signified communal tasks that the individual contributed towards, how were these tasks distinguished from one another? All the cords within a color band would all be the same color, so color would not have been a distinguishing factor. However, their perceived markedness could influence the order in which the tasks appeared on the primary cord, from the highest ranked task to the lowest ranked task.

Beyond cord color signs, khipukamayuqs could also have manipulated any number of additional physical features to signify information at the cord level. For instance, the spin/ply direction (S-spun/Z-plied vs. Z-spun/S-plied) of the cord, the fiber used to the make the cord (whether of camelid fiber, cotton fiber, or something else entirely), and attachment type (recto vs. verso) could all have been used to produce marked/unmarked signs. Additionally, each cord could have any number of subsidiary cords attached to it to modify its numerical as well non-numerical meanings. For instance, a subsidiary cord might feature a different fiber type than the pendant cord it is attached to and have a numerical value recorded on it that appends that of the pendant cord. All of these potential sign-vehicles should be further researched to identify whether they were actively used to produce conventionalized marked/unmarked sign pairs. Such marked and unmarked cord-level signs would have made it possible for khipukamayuqs to relate cords to one another in even further nuanced ways beyond just their position on a cord and their color.

Finally, at the individual knot level, relationships between knot signs were signified through three main vehicles: knot position on a cord, knot type, and knot direction. Recall from Chapter 1 that numbers were signified on cords in a decimal notation, where units in the 1's place were tied as knots at the end of the cord, farthest away from the primary cord. Each subsequent decimal place value (10's, 100's, etc.) was placed at standard increments higher up on the attached cord, closer to the primary cord (Locke 1923). In this way, the position in which a knot was tied on a cord signified its numerical decimal place value. Recall as well that three knot types were used to signify numerical values at the different decimal positions on a cord: figure-eight knots, long knots, and single knots. Figure-eight and long knots were used solely to signify numbers in the 1's position. Figure-eight knots were only used to signify the value "1," whereas long knots could signify larger numbers (2-9) in the 1's position, based on how many times the cord was wrapped around itself before being tied off. Single overhand knots, on the other hand, were used exclusively in the tens and higher places and could be grouped together at a decimal place position. Thus, a cord with two single overhand knots in the 100's place, 2 single overhand knots in the 10's place, and a long-knot wrapped three times around a cord, would have the overall numerical value "223."

As I discussed in Chapter 3, the knots forming these numbers were additionally related to one another by knot direction dicent symbols. In Quechua, a compound number like "13" is spoken as "ten, possessor of three," where the higher decimal place is unmarked (and thus inclusive of the lower decimal place). Inka khipukamayuqs seem to have signified this same grammatical relationship between decimal places by using knot direction as an inflectional sign for designating the possession of one knot by another knot or set of knots on the same cord. Specifically, they conventionally used Z-knots to denote the unmarked, higher decimal places (single knots) and S-knots to denote the marked, lower decimal places (figure-eight and long knots).

Overall, the dicent symbols used by khipukamayuqs as non-numerical signs did not relate to each other on an equal basis. Rather, some signs had nested, hierarchical priority over other signs. For instance, khipu-level signs, like the base color of the khipu, informed all other signs on the khipu, indicating that the khipu as a whole, for instance, was about net debit arithmetic operations or aggregate-level labor accounting. On the other end of the spectrum, knot direction signs generally seem to have signified the relationship between individual knots, replicating the nuances of Quechua numerical grammar. In this way, an individual knot direction sign had less influence on other signs than higher order, khipu-level signs that informed the interpretation of all the other signs on the khipu. Thus, in summary, khipukamayuqs related khipu signs to one another through a sophisticated system of nested dicent symbols. Each nested level predicated a finer grained subset of the khipu, such that khipukamayuqs were able to denote the temporal and hierarchical structure of signs, grammatical differences between signs, and broad contextual information that was true for multiple signs in the khipu.

6.3 Implications for Interpreting the Inka Past from Khipus

At the outset of the dissertation, I mentioned that the Inka are said to have recorded a vast amount of information on khipus from storehouse accounting, to histories, calendars, and songs (Ascher and Ascher 1997:74; Urton 2003:3). Without a strong understanding of how these different genres would have been recorded, though, much of khipu research to this point has been focused on what can be readily interpreted: the numbers. This has led researchers such as Gary Urton to tell Inka history through the lens of an *annales* style of historiography—that is, one focused on the economic and statistical machinations of the Inka empire, as interpreted from the numerical values on khipus through time and space (Urton 2017).

My grammatical findings here, though, suggest that, in the future, we will be able to expand our Inka khipu historiographic toolkit and incorporate a broader range of primary source material. For instance, Spanish chroniclers tell us that khipus were used by the Inka as primary sources for life histories detailing the deeds of Inka rulers and set alongside their mummies (Julien 2000:128-129). It is not completely understood what parts of these life histories would have been recorded in khipus and which parts recorded in other semiotic forms like memorized songs. However, the deeds of Inka rulers could have been recorded in khipus using colors to designate actions the ruler pursued or entities the ruler encountered in a temporally ordered sequence, just as arithmetic actions were organized in a logical sequence in the Inkawasi khipus. Furthermore, potential cord-level signs like ply direction, attachment type, and the use of subsidiary cords all have the potential to inflect cords in relation to one another, forming more complicated marked and unmarked relationships between signs than cord color alone can signify. While the details for how such relationships could be signified still need further study, my work in this dissertation suggests that sequential, temporally-ordered, narrative genres could have been represented using the same conventionalized methods of non-numerical representation as were used in the standard Inka administrative khipu semiotic toolkit.

It might, thus, be misleading to consider narrative khipus as a separate "kind" of khipu from the rest (i.e. khipus that looked fundamentally different or used different types of signs entirely). Khipus that employed narrative strategies might have activated more non-numerical signs in their composition and been more expressive than say, a blank white khipu with only numerical values to distinguish one cord from the other. However, I hope I have verified that the grammatical principles necessary to represent complicated narrative processes were all in place even within standard Inka administrative khipus. As I have demonstrated over the course of this chapter, Inka khipukamayuqs employed a rich combination of grammatical techniques in khipus throughout the KDB to denote temporality, hierarchy, contextual information, and actions—all in addition to numerical data. We might expect, then, to find important narrative elements within khipus that otherwise look like standard accounting khipus. If we can identify more of these non-numerical and narrative elements within Inka khipus, it will be possible to write even richer Inka histories, using greater amounts of non-numerical information as primary source material.

6.4 Final Remarks

All in all, this is an exciting time to study khipus. As I mentioned at the outset of the dissertation, a great deal of recent progress has been made by scholars focused on understanding post-conquest khipu signs. My findings build off of their hard work and make it possible to begin to interpret knot direction signs, cord color pairings, and color patterns on khipus from across the Inka empire. While Inka khipukamayuqs do not seem to have employed phonetic signs, they signified non-numerical information using an elaborate system of dicent symbolic legisigns. These signs were widely conventionalized and used across Tawantinsuyu in a way that is functionally equivalent to a writing system. In this chapter, I have additionally synthesized a preliminary grammar of Inka khipu signs—an exposition of how the khipu signs generally worked for the Inka. This grammar gives us an idea of how signs were interpreted, as well as the ways in which they were temporally, linguistically, and conceptually related to one another through the nested semiotic structure of a khipu.

To fully interpret these sophisticated semiotic practices, though, we must continue systematic decipherment efforts like I have pursued in this dissertation, so that we may further expand our khipu vocabulary. Expanding our vocabulary will allow us to better understand what the Inka were recording in quantitative, administrative records as well as to recognize and interpret narrative elements within Inka khipus. Continued multidisciplinary work between ethnography, archaeology, and other related fields will make it possible to continue deciphering dicent symbols. As I have demonstrated in this dissertation, it is only by drawing on the full Andean universe of signs—from weaving, to camelid herding, and numerical grammar—that we might ultimately be able to interpret the full range of Inka khipu signs once more.

References

Agresti, Alan

2002 *Categorical Data Analysis*. John Wiley & Sons, Hoboken, NJ.

Arnold, Denise Y.

2014 Textiles, knotted khipus, and a semiosis in common: Towards a woven language of documentation in the Andes. In *Textiles, Technical Practice and Power in the Andes*, edited by D. Y. Arnold and Penelope Dransart, pp. 23–45. Archetype Publications, London.

Arnold, Denise Y., and Elvira Espejo

2012 Andean weaving instruments for textile planning: The waraña coloured thread-wrapped rods and their pendant cords. *Indiana* 29:173–200.

Arnold, Denise Y., and Juan de Dios Yapita

2001 *River of Fleece, River of Song: Singing to the animals, an Andean poetics of creation*. Verlag Anton Saurwein, Markt Schwaben, Germany.

2006 *The metamorphosis of heads: textual struggles, education, and land in the Andes*. University of Pittsburgh Press, Pittsburgh, PA.

Ascher, Marcia

2005 How Can Spin, Ply, and Knot Direction Contribute to Understanding the Quipu Code? *Latin American Antiquity* 16(1):99–111.

Ascher, Marcia, and Robert Ascher

1997 *Mathematics of the Incas: Code of the Quipu*. Dover Publications, Mineola, New York.

Baitzel, Sarah I.

2016 Color, Structure, and Society in Tiwanaku Burial Textiles. Paper presented at the 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Bard, Kathryn A.

2015 *An Introduction to the Archaeology of Ancient Egypt*. Wiley-Blackwell, Malden, MA.

Bertonio, Ludovico

1984 [1612] *Vocabulario de la lengua aymara*. Edited by Xavier Albó and Félix Layme. Facsimile edition. CERES, IFEA, MUSEF, La Paz/Cochabamba.

Boone, Elizabeth Hill
2011 The Cultural Category of Scripts, Signs, and Pictographies. In *Their Way of Writing: Scripts, Signs, and Pictographies in Pre-Columbian America*, edited by Elizabeth Hill Boone and Gary Urton, pp. 379-390. Dumbarton Oaks Research Library and Collection, Washington, D.C.

Bouysse-Cassagne, Thérèse
1986 Urco and uma: Aymara concepts of space. In *Anthropological History of Andean Polities*, edited by John V. Murra, Nathan Wachtel, and Jacques Revel, pp. 201 - 227. Cambridge University Press, Cambridge.

Brokaw, Galen
2010 *A History of the Khipu*. Cambridge University Press, Cambridge.

Cabello Valboa, M.
1951 [1586] *Miscelánea antártica*. Universidad Nacional Mayor de San Marcos, Lima.

Calancha, Antonio de la
1638 *Coronica moralizada del orden de San Agustin en el Peru con sucesos egenplares en esta monarquia*. Pedro Lacavalleria, Barcelona.

Cereceda, Verónica
1986 The semiology of Andean textiles: the talegas of Isluga. In *Anthropological History of Andean Polities*, edited by John V. Murra, Nathan Wachtel, and Jacques Revel, pp. 149–173. Cambridge University Press, Cambridge.

1987 Aproximaciones a una estetica andina: de la bellaza al tinku. In *Tres reflexiones sobre el pensamiento andino*, edited by Thérèse Bouysse-Cassagne, Olivia Harris, Tristan Platt, and Verónica Cereceda, pp. 133–226. HISBOL, La Paz.

Champollion, Jean-François
1822 *Lettre à M. Dacier relative à l'alphabet des hiéroglyphes phonétiques*. Firmin Didot, Paris.

1824 *Précis du système hiéroglyphique des anciens Égyptiens*. Imprimerie royale, Paris.

Chandler, Daniel
2007 *Semiotics: The Basics*. 2nd ed. Routledge, London.

Clark, John E.
1995 Craft Specialization as an Archaeological Category. *Research in Economic Anthropology* 16:267–294.

Clindaniel, Jon
2018 Are Inka Khipu Knots Anything More than Numbers? A Computational Investigation. Paper presented at the 83rd Annual Meeting of the Society for American Archaeology, Washington, D.C.

Clindaniel, Jon, and Gary Urton
2017 Quipus de Pachacamac: hacia la estandarización de las convenciones de signos en el Tawantinsuyu. In *Pachacamac: El Oráculo en el horizonte marino del sol poniente*, edited by Denise Pozzi-Escot, pp. 274-287. Banco de Credito del Perú, Lima.

Clindaniel, Jon, Gary Urton, and Alejandro Chu
In Press Los khipus de Incahuasi. In *Khipus*, edited by Cecilia Pardo Grau and Gary Urton. Museo de Arte de Lima, Lima.

Cobo, Bernabé
1990 [1653] *Inca Religion and Customs*. Edited by Roland Hamilton. University of Texas Press, Austin.

Cohen, Jacob
1992 Statistical Power Analysis. *Current Directions in Psychological Science* 1(3):98-101.

Conklin, William J.
2002 A Khipu Information String Theory. In *Narrative Threads: Accounting and Recounting in Andean Khipu*, edited by Jeffrey Quilter and Gary Urton, pp. 53-86. University of Texas Press, Austin.

Conover, William J.
1971 *Practical nonparametric statistics*. John Wiley & Sons, New York.

Costin, Cathy Lynne
1991 Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production. *Archaeological Method and Theory* 3:1–56.

Covey, R. Alan
2000 Inka Administration of the Far South Coast of Peru. *Latin American Antiquity* 11(2):119–138.

D'Altroy, Terence N.
2015 *The Incas, Second Edition*. Wiley Blackwell, Malden, MA.

DeFrancis, John
1989 *Visible Speech: The Diverse Oneness of Writing Systems*. University of Hawaii Press, Honolulu.

Díaz, Luisa, and Francisco Vallejo
2002 Armatambo y el dominio incaico en el valle de Lima. *Boletín de Arqueología* PUCP 6:355–374.

Dransart, Penelope
2002 *Earth, Water, Fleece, and Fabric: An ethnography and archaeology of Andean camelid herding*. Routledge, London and New York.

2016 *The sounds and tastes of colours: hue and saturation in Isluga textiles*. Nuevo Mundo Mundos Nuevos.

Eco, Umberto
1976 *A Theory of Semiotics*. Indiana University Press, Bloomington.

2000 *Kant and the Platypus: Essays on Language and Cognition*. Translated by Alastair McEwen. Harcourt, San Diego.

Flad, Rowan K.
2007 Rethinking the Context of Production through an Archaeological Study of Ancient Salt Production in the Sichuan Basin, China. *Archaeological Papers of the American Anthropological Association* 17(1):108–128.

Goepfert, Nicolas, and Gabriel Prieto
2016 Offering Lllamas to the Sea: The Economic and Ideological Importance of Camelids in the Chimu Society, North Coast of Peru. In *The Archaeology of Andean Pastoralism*, edited by J. M. Capriles and N. Tripcevich, pp. 197–210. University of New Mexico Press, Albuquerque.

Hall, Stuart
1980 Encoding/Decoding. In *Culture, Media, Language: Working Papers in Cultural Studies*, 1972-1979, edited by Stuart Hall, Dorothy Hobson, Andrew Lowe, and Paul Willis, pp. 128–138. Hutchinson, London.

Hidalgo, Guillermo, and Jorge Focacci
1986 Multietnicidad en Arica, S. XVI. Evidencias etnohistóricas y arqueológicas. *Chungara: Revista de Anthropología Chilena* (16/17):137–147.

Hodge, Robert, and Gunther Kress
1988 *Social Semiotics*. Cornell University Press, Ithaca.

Hyland, Sabine
2014 Ply, Markedness, and Redundancy: New Evidence for How Andean Khipus Encoded Information. *American Anthropologist* 116(3):1–6.

2016 How Khipus Indicated Labour Contributions in an Andean Village: An Explanation of Colour Banding, Seriation, and Ethnocategories. *Journal of Material Culture* 21(4): 490–509.

2017 Writing with Twisted Cords: The Inscriptive Capacity of Andean Khipus. *Current Anthropology* 58(3):412–419.

Hyland, Sabine, Gene A. Ware, and Madison Clark
2014 Knot Direction in a Khipu/Alphabetic Text from the Central Andes. *Latin American Antiquity* 25(2):189–197.

Hyslop, John
1985 *Inkawasi, the New Cuzco: Cañete, Lunahuaná, Peru*. Vol. 234. BAR International Series, Oxford.

Jakobson, Roman
1971 Linguistics and Communication Theory. In *Selected Writings*, pp. 570–579. Mouton, The Hague.

Jones, Eric, Travis Oliphant, and Pearu Peterson
2001 SciPy: Open Source Scientific Tools for Python.

Julien, Catherine J.
1988 How Inca Decimal Administration Worked. *Ethnohistory* 35(3):257–279.

2000 *Reading Inca History*. University of Iowa Press, Iowa City.

Levine, Terry Yarov
1987 Inka Labor Service at the Regional Level: The Functional Reality. *Ethnohistory* 34(1):14–46.

Liszka, James Jakob
1996 *A General Introduction to the Semeiotic of Charles Sanders Peirce*. Indiana University Press, Bloomington and Indianapolis.

Locke, L. Leland
1923 *The Ancient Quipu or Peruvian Knot Record*. The American Museum of Natural History, New York.

Mackey, Carol
1970 *Knot Records in Ancient and Modern Peru*. Unpublished Ph.D. Dissertation, University of California, Berkeley.

Mannheim, Bruce
1986 Popular Song and Popular Grammar, Poetry and Metalanguage. *Word* 37(1):45–75.

Marcone Flores, Giancarlo, and Rodrigo Areche Espinola
2015 El valle de Cañete durante los períodos prehispánicos tardíos: perspectivas desde El Huarco – Cerro Azul. *Cuadernos del Qhapaq Ñan* 3:48–68.

McKinney, Wes
2010 Data Structures for Statistical Computing in Python. *Proceedings of the 9th Python in Science Conference*:51–56.

Medrano, Manuel, and Gary Urton
2018 Toward the Decipherment of a Set of Mid-Colonial Khipus from the Santa Valley, Coastal Peru. *Ethnohistory* 65(1):1–23.

Michalowski, Piotr
1994 Writing and Literacy in Early States: A Mesopotamianist Perspective. In *Literacy: Interdisciplinary Conversations*, edited by Deborah Keller-Cohen, pp. 49-70. Hampton Press, Cresskill, NJ.

Molina, Cristobal de
1988 [1573] *Relación de las Fábulas y Ritos de los Incas*. Edited by Henrique Urbano and Pierre Duviols. Historia 16, Madrid.

Murra, John V.
1978 *La organización económica del estado Inca*. Translated by Daniel Wagner. Siglo XXI Editores, México.

Murúa, Martín de
2001 [1590] *Historia general del Perú*. Edited by Manuel Ballesteros Gaibrois. Dastin Historia, Madrid.

Nöth, Winfried
1990 *Handbook of Semiotics*. Indiana University Press, Bloomington and Indianapolis.

Ochoa, Jorge A. Flores
1978 Classification et dénomination des camélidés sud-américains. *Annales, Économies, Sociétés, Civilisations* 33(5–6):1006–1016.

Parmentier, Richard J.
1994 Peirce Divested for Nonintimates. In *Signs in Society: Studies in Semiotic Anthropology*, pp. 3–22. Indiana University Press, Bloomington and Indianapolis.

Pärssinen, Martti
1992 *Tawantinsuyu: The Inca State and Its Political Organization*. Finnish Historical Society, Helsinki.

Pedregosa, F., G. Varoquaux, A. Gramfort, V. Michel, B. Thirion, O. Grisel, M. Blondel,

P. Prettenhofer, R. Weiss, V. Dubourg, J. Vanderplas, A. Passos, D. Cournapeau, M. Brucher, M. Perrot, and E. Duchesnay
2011 Scikit-learn: Machine learning in Python. *Journal of Machine Learning Research* 12:2825–2830.

Peirce, Charles Sanders
1955 Logic as Semiotic: The Theory of Signs. In *Philosophical Writings of Peirce*, edited by Justus Buchler, pp. 98–119. Dover Publications, New York.

Platt, Tristan
1986 Mirrors and maize: the concept of yanantin among the Macha of Bolivia. In *Anthropological History of Andean Polities*, edited by John V. Murra, Nathan Wachtel, and Jacques Revel, pp. 228–259. Cambridge University Press, Cambridge.

1987 The Andean Soldiers of Christ. Confraternity organization, the Mass of the Sun and regenerative warfare in rural Potosi (18th-20th centuries). *Journal de la Société des Américanistes* 73:139–191.

Quilter, Jeffrey
2002 Yncap Cimin Quipococ's Knots. In *Narrative Threads: Accounting and Recounting in Andean Khipu*, edited by Jeffrey Quilter and Gary Urton, pp. 197-222. University of Texas Press, Austin.

Radicati di Primeglio, Carlos
2006 *Estudios sobre los Quipus*. Edited by Gary Urton. UNMSM, Lima.

Rivera, Mario A.
1991 The Prehistory of Northern Chile: A Synthesis. *Journal of World Prehistory* 5(1):1–47.

Rostworowski, Maria
1986 La región del Colesuyu. *Chungara: Revista de Antropología Chilena* (16/17):127-135.

Salomon, Frank
2001 How an Andean "Writing Without Words" Works. *Current Anthropology* 42(1):1-27.

2004 *The Cord Keepers: Khipus and Cultural Life in a Peruvian Village*. Duke University Press, Durham.

2013 The Twisting Paths of Recall: Khipu (Andean cord notation) as artifact. In *Writing as Material Practice: Substance, surface, and medium*, edited by K. E. Piquette and R. D. Whitehouse, pp. 15–43. Ubiquity Press, London.

Sampson, Geoffrey
1985 *Writing Systems: A Linguistic Introduction*. Stanford University Press, Stanford, CA.

Sarmiento de Gamboa, P.
1942 [1572] *Historia de los incas*. Emecé Editores, Buenos Aires.

Savan, David
1988 *An Introduction to C.S. Peirce's Full System of Semeiotic*. Toronto Semiotic Circle, Toronto.

Splitstoser, Jeffrey C.
2014 Practice and meaning in spiral-wrapped batons and cords from Cerrillos, a Late Paracas site in the Ica Valley, Peru. In *Textiles, Technical Practice, and Power in the Andes*, edited by Penny Arnold Denise Y.; Dransart, pp. 46–82. Archetype Publications, London.

Urton, Gary
1994 A New Twist in an Old Yarn: Variation in Knot Directionality in the Inka Khipus. *Baessler-Archiv* 42(2):271–305.

1997 *The Social Life of Numbers: A Quechua Ontology of Numbers and Philosophy of Arithmetic*. University of Texas Press, Austin.

1998 From Knots to Narratives: Reconstructing the Art of Historical Record Keeping in the Andes from Spanish Transcriptions of Inka Khipus. *Ethnohistory* 45(3):409-438.

2001 A Calendrical and Demographic Tomb Text from Northern Peru. *Latin American Antiquity* 12(2):127-147.

2002 Recording Signs in Narrative-Accounting Khipu. In *Narrative Threads: Accounting and Recounting in Andean Khipu*, edited by Jeffrey Quilter and Gary Urton, pp. 171–196. University of Texas Press, Austin.

2003 *Signs of the Inka Khipu*. University of Texas Press, Austin.

2014 From Middle Horizon cord-keeping to the rise of Inka khipus in the central Andes. *Antiquity* 88:205–221.

2015 The State of Strings: Khipu Administration in the Inka Empire. In *The Inka Empire: A Multidisciplinary Approach*, edited by Izumi Shimada, pp. 149–164. University of Texas Press, Austin.

2017 *Inka History in Knots: Reading Khipus as Primary Sources*. University of Texas Press, Austin, TX.

Urton, Gary, and Carrie J. Brezine
2007 Information Control in the Palace of Puruchuco. In *Variations in the Expression of Inka Power*, pp. 357–84. Dumbarton Oaks, Washington, D.C.

2011 Khipu Typologies. In *Their Way of Writing: Scripts, Signs and Pictographies in Pre-Columbian America*, edited by Elizabeth Hill Boone and Gary Urton, pp. 319–352. Dumbarton Oaks Research Library and Collection, Washington, D.C.

Urton, Gary, and Alejandro Chu
2015 Accounting in the King's Storehouse: The Inkawasi Khipu Archive. *Latin American Antiquity* 26(4):512–529.

2019 The Invention of Taxation in the Inka Empire. *Latin American Antiquity* 30(1):1-16.

Urton, Gary, and Adriana Von Hagen
2015 Introduction. In *Encyclopedia of the Incas*, edited by Gary Urton and Adriana Von Hagen, pp. 1-10. Rowman & Littlefield, Lanham, MD.

Vega, Garcilaso de la
1918 [1609] *Los Comentarios Reales de Los Incas*. Edited by Horacio H. Urteaga. Vol. 2. Imprenta Y Libreria Sanmarti Y Ca., Lima.

Weber, Max
1968 [1922] Bureaucracy. In *Economy and Society: an Outline of Interpretive Sociology*, edited by G. Roth and Wittich C., translated by E. Fischoff, H. Gerth, A.M. Henderson, F. Kolegar, C. Wright Mills, T. Parsons, M. Rheinstein, G. Roth, E. Shils, and C. Wittich, pp. 956–1005. Bedminster Press, New York.

Wheeler, Jane C., A. J. F. Russel, and Hilary Redden
1995 Llamas and Alpacas: Pre-conquest Breeds and Post-conquest Hybrids. *Journal of Archaeological Science* 22:833–840.

Zuidema, R. Tom
1964 *The Ceque System: The Social Organization of the Capital of the Inca*. E.J. Brill, Leiden.

2015 Ritual Calendar. In *Encyclopedia of the Incas*, edited by Gary Urton and Adriana Von Hagen, pp. 60-63. Rowman & Littlefield, Lanham, MD.

Appendix A

Supplementary Code

A.1 Chapter 3 Supplementary Code

First, I loaded all the packages I needed to perform my analysis:

```
In [1]: %matplotlib inline
        import numpy as np # Version 1.14.5
        import pandas as pd # Version 0.22.0
        from scipy import stats # Version 1.1.0
        import seaborn as sns # Version 0.9.0
        import matplotlib.pyplot as plt # Version 1.5.1
```

I then indexed all of the exacavated khipus that form the Inkawasi, Pachacamac, Puruchuco, and Armatambo archives by listing out their khipu IDs. Next, I read in pre-wrangled KDB khipu data from CSV (available as supplemental online material for the dissertation on DASH, Harvard's open-access online repository: https://dash.harvard.edu/) to a pandas dataframe to identify any remaining khipus in the KDB for further analysis.

```
In [2]: index = {}
        index['Inkawasi'] = ['JC001', 'JC002', 'JC003', 'JC004', 'JC005', 'JC006',
                             'JC007', 'JC008', 'JC009', 'JC010', 'JC011', 'JC012',
                             'JC013', 'JC014', 'JC015', 'JC016', 'JC017', 'JC018',
                             'JC019', 'JC020', 'JC021', 'JC022', 'JC023', 'UR255',
                             'UR256', 'UR257', 'UR258', 'UR259', 'UR260', 'UR261',
                             'UR262', 'UR263', 'UR264', 'UR265', 'UR266', 'UR267A',
                             'UR267B', 'UR268', 'UR269', 'UR270', 'UR271', 'UR272',
                             'UR273A', 'UR273B', 'UR274A', 'UR274B', 'UR275', 'UR276',
                             'UR277', 'UR278', 'UR279', 'UR280'
                            ]
```

```python
print 'Number of khipus from Inkawasi: ', len(index['Inkawasi'])

index['Pachacamac'] = ['UR1097', 'UR1099', 'AS101 - Part 1', 'AS101 - Part 2',
                       'UR1102', 'UR1104', 'AS110', 'AS111', 'AS112', 'UR1118', 'UR1119',
                       'UR1121', 'AS125', 'UR1131', 'AS134', 'AS139', 'UR1144',
                       'UR1145', 'UR1151', 'AS156', 'AS158', 'UR1163', 'UR1165',
                       'UR1167', 'AS170', 'AS172', 'UR1175', 'AS187', 'AS188', 'AS189',
                       'UR115', 'UR1095', 'UR1096', 'UR123', 'UR124', 'UR126', 'UR1034',
                       'AS075', 'HP001', 'HP002', 'HP003', 'HP004', 'HP005', 'HP006',
                       'HP007', 'HP008', 'HP009', 'HP010', 'HP011', 'HP012', 'HP013',
                       'HP014', 'HP017', 'HP018', 'HP019', 'HP020', 'HP021', 'HP022',
                       'HP023', 'HP024', 'HP025', 'HP026', 'HP027', 'HP028', 'HP029',
                       'HP030', 'HP031', 'HP032', 'UR196', 'UR197', 'UR199', 'UR200',
                       'UR201', 'UR202', 'UR208', 'UR212', 'UR213', 'UR214', 'UR216',
                       'UR218', 'UR226', 'UR230', 'UR243', 'UR245', 'UR244', 'UR246',
                       'UR247', 'UR248', 'UR249', 'UR253', 'UR254'
                      ]
print 'Number of khipus from Pachacamac: ', len(index['Pachacamac'])

index['Puruchuco'] = ['UR0%s' % i for i in xrange(60,83)]
print 'Number of khipus from Puruchuco: ', len(index['Puruchuco'])

index['Armatambo'] = ['UR%s' % i for i in xrange(281,295)]
print 'Number of khipus from Armatambo: ', len(index['Armatambo'])


# Remaining Khipus not from Inkawasi, Pachacamac, Puruchuco, or Armatambo
#(in which'UR291A', 'UR292A' have 'A' suffixes in KDB)in the database:
master_df = pd.read_csv('Data\Master_Cord_Data_8_1_2018.csv')
remaining_index = list(set(master_df.Khipu.unique()) - \
                       set(index['Armatambo']) - set(index['Puruchuco']) - \
                       set(index['Pachacamac']) - set(index['Inkawasi']) - \
                       set(['UR291A', 'UR292A']))
# Clean up AS titles so they're the same as the filename:
remaining_index.append('AS090'); remaining_index.append('AS067');
remaining_index.remove('AS090/N2'); \
    remaining_index.remove('AS067/MA29'); remaining_index.remove('AS067/MA029')
remaining_index.append('AS061'); remaining_index.remove('AS061/MA036')
index['All'] = remaining_index
```

```
    print 'Number of all remaining khipus in the KDB: ', len(index['All'])

Number of khipus from Inkawasi:  52
Number of khipus from Pachacamac:  91
Number of khipus from Puruchuco:  23
Number of khipus from Armatambo:  14
Number of all remaining khipus in the KDB:  446
```

I then gathered data on S and Z knot types and frequencies using the function `count_SZ()` below. The function reads in individual xlsx files for each khipu (featuring complete summaries of the data recorded for each khipu in the KDB, including knot direction for each knot on each cord), as the required data for this analysis is not featured in the cleaned cord summary file `Master_Cord_Data_8_1_2018.csv` that I use above. Each one of these individual khipu data files is available on DASH as supplemental online material for the dissertation.

```
In [3]: def count_SZ(khipu_index, khipu_folder_path):
            ID, Single_S, Single_Z, Long_S, Long_Z, E_S, E_Z = [[] for _ in range(7)]
            for i in khipu_index:
                df = pd.read_excel('%s\Khipu_%s.xlsx' % (khipu_folder_path,i), parse_cols = \
                    range(5,14))
                ID.append(i)
                count_Single_S, count_Single_Z, count_Long_S, count_Long_Z, count_E_S, \
                    count_E_Z = [0 for _ in range(6)]
                for i in df.iterrows():
                    if i[1].astype(str).str.contains('/S').any():
                        count_Long_S += \
                            len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/S)')])
                        count_E_S += \
                            len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/S)')])
                        count_Single_S += \
                            len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/S)')])
                    if i[1].astype(str).str.contains('Z').any():
                        count_Long_Z += \
                            len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/Z)')])
                        count_E_Z += \
```

```
                    len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/Z)')])
                count_Single_Z += \
                    len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/Z)')])

            Single_S.append(count_Single_S), Single_Z.append(count_Single_Z)
            Long_S.append(count_Long_S), Long_Z.append(count_Long_Z)
            E_S.append(count_E_S), E_Z.append(count_E_Z)
        return Single_S, Single_Z, Long_S, Long_Z, E_S, E_Z
```

```
In [4]: Single_S = {}; Single_Z = {}; Long_S = {}; Long_Z = {}; E_S = {}; E_Z = {}

        for i in index.keys():
            Single_S[i], Single_Z[i], Long_S[i], Long_Z[i], E_S[i], E_Z[i] = \
                count_SZ(index[i],'Data\Individual_All_Khipus')
```

Note that the number of Z-knots overall is much higher (and statistically significant under binomial test, p<0.01) than the number of S-knots for all khipus (except those at Armatambo):

```
In [5]: knot_direction_counts = {}; total_sknots = {}; total_zknots = {}

        for i in index.keys():
            knot_direction_counts[i] = pd.DataFrame([Single_S[i], Single_Z[i], Long_S[i], \
                Long_Z[i], E_S[i], E_Z[i]]).T
            knot_direction_counts[i].columns = \
                ['Single_S', 'Single_Z', 'Long_S', 'Long_Z', 'E_S', 'E_Z']
            knot_direction_counts[i].index = index[i]

            total_sknots[i] = \
                knot_direction_counts[i]['Single_S'].sum() \
                + knot_direction_counts[i]['Long_S'].sum()\
                + knot_direction_counts[i]['E_S'].sum()
            total_zknots[i] = \
                knot_direction_counts[i]['Single_Z'].sum() \
                + knot_direction_counts[i]['Long_Z'].sum() \
                + knot_direction_counts[i]['E_Z'].sum()

            print "%s:" % i
            print "Total S-knots:", total_sknots[i]
            print "Total Z-knots:", total_zknots[i]
```

```
        print "Probability of larger Z-knot count:", \
            stats.binom_test([total_zknots[i], total_sknots[i]], alternative='greater')
        print '########################'
```

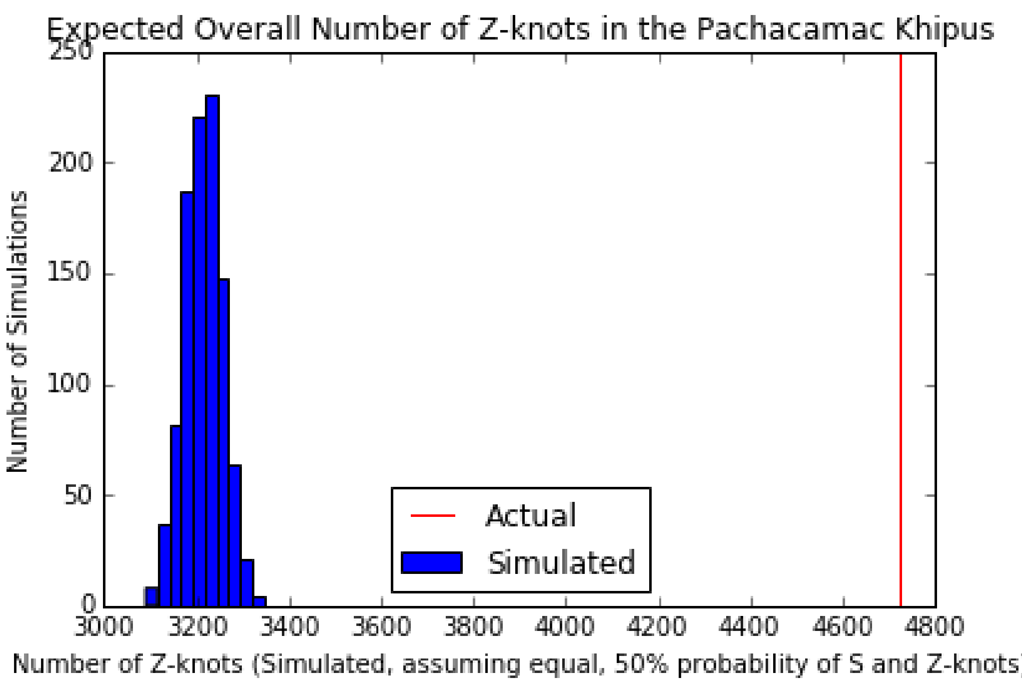
```
Pachacamac:
Total S-knots: 1705
Total Z-knots: 4725
Probability of larger Z-knot count: 6e-323
########################
Inkawasi:
Total S-knots: 1704
Total Z-knots: 6209
Probability of larger Z-knot count: 0.0
########################
All:
Total S-knots: 15461
Total Z-knots: 20689
Probability of larger Z-knot count: 2.9404457151227775e-167
########################
Armatambo:
Total S-knots: 608
Total Z-knots: 485
Probability of larger Z-knot count: 0.9999131380694952
########################
Puruchuco:
Total S-knots: 241
Total Z-knots: 575
Probability of larger Z-knot count: 1.3912329872018294e-32
########################
```

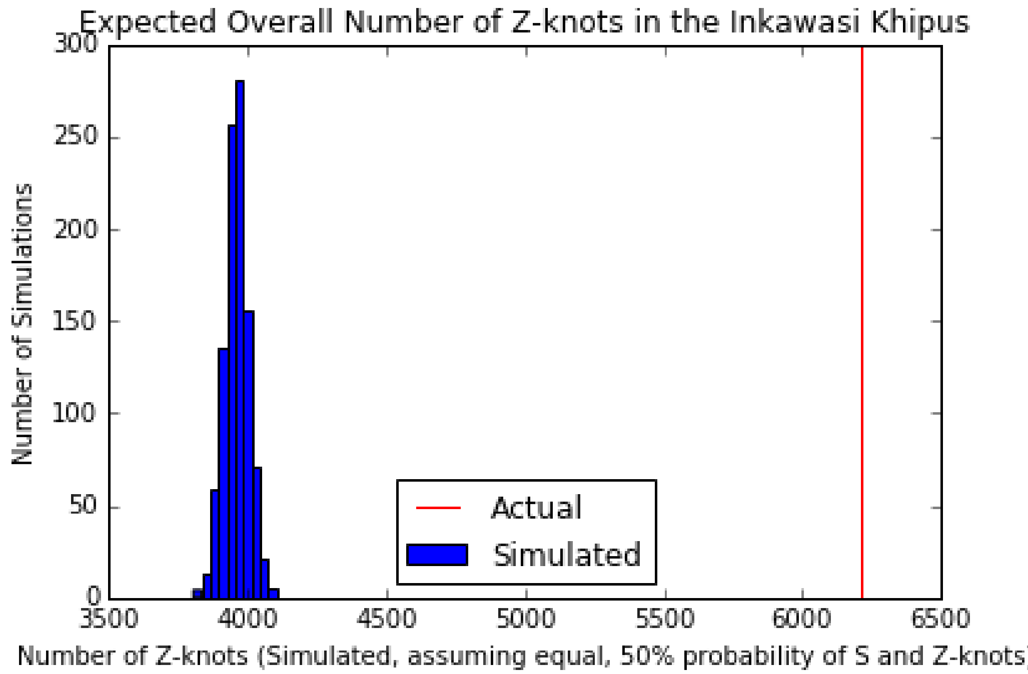
I then plotted the results of a binomial simulation to illustrate how far away the actual results are from a scenario where S- and Z-knots were used at an equal frequency in each archive.

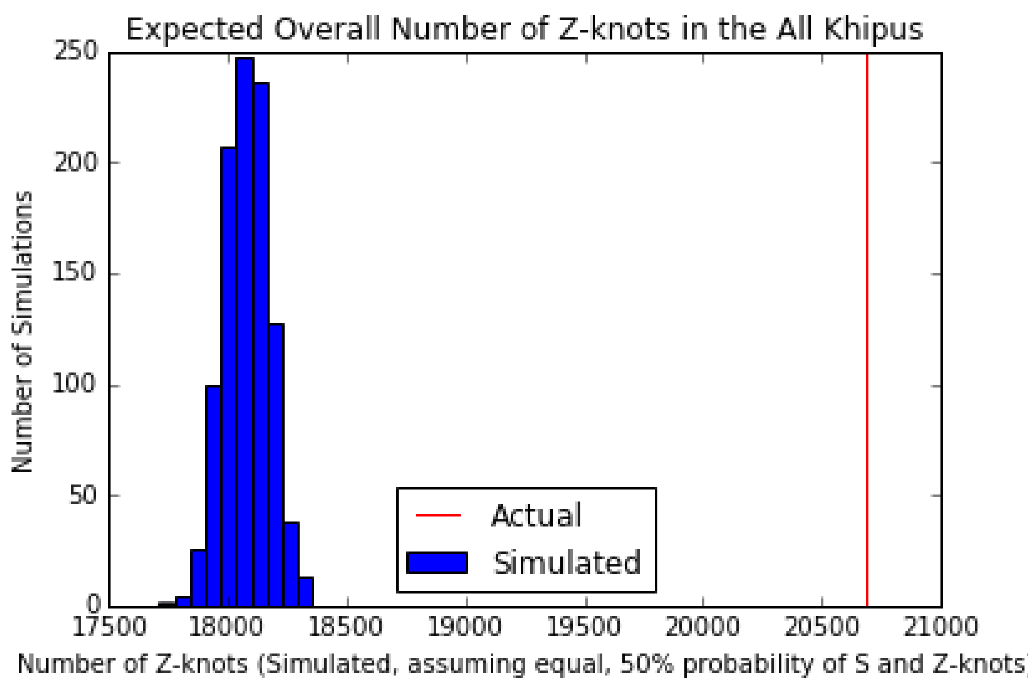
```
In [6]: #Simulate 50/50 Binomial Distribution odds for expected number of Z-knots overall:
        simulated_binom_data = {}
```

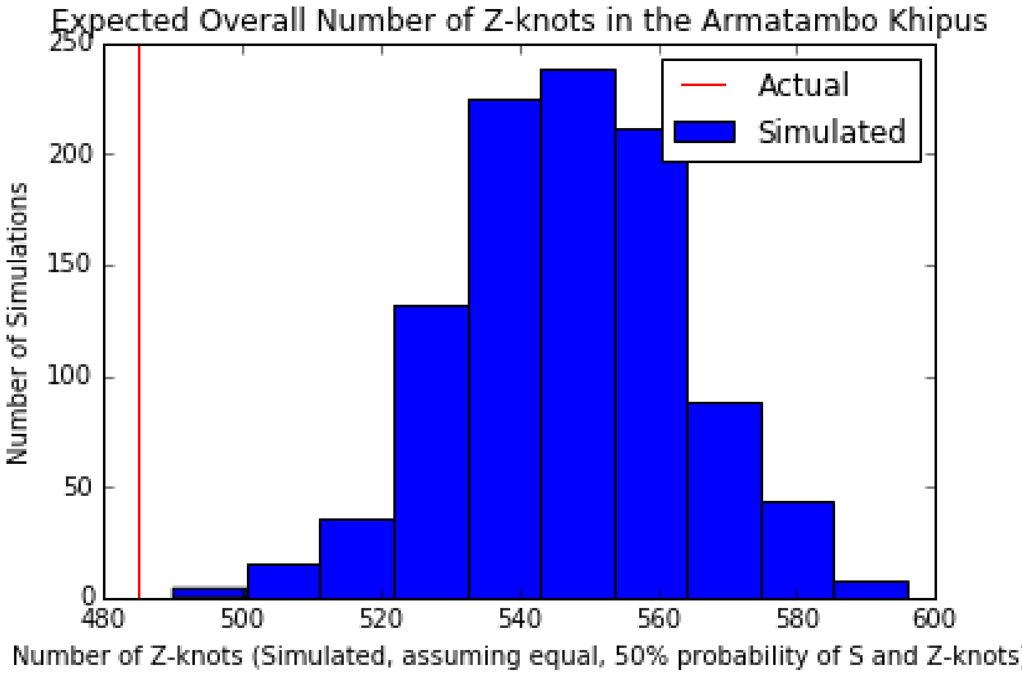
```
    for i in index.keys():
        total_knots = np.sum(total_zknots[i]+total_sknots[i])
        simulated_binom_data[i] = [sum(np.random.randint(0, 2, size=total_knots))  \
                                        for j in np.arange(1000)]
```

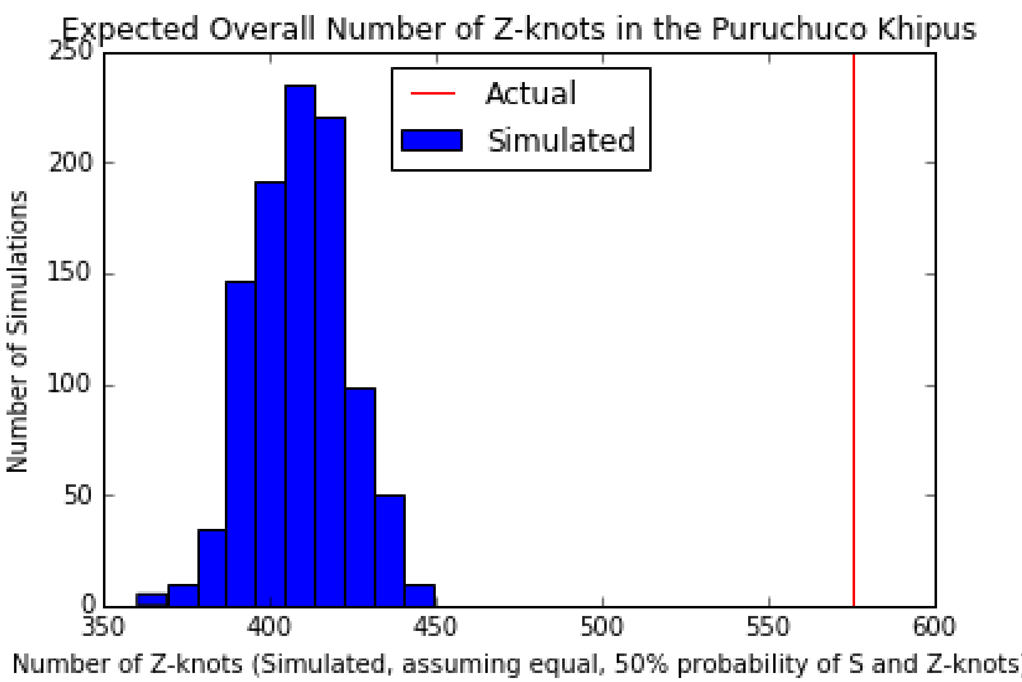
```
In [7]: for i in index.keys():
            plt.hist(simulated_binom_data[i], label='Simulated')
            plt.title("Expected Overall Number of Z-knots in the %s Khipus" % i)
            plt.xlabel("Number of Z-knots (Simulated, assuming equal, 50% probability of S \
                        and Z-knots)")
            plt.ylabel("Number of Simulations")
            plt.axvline(x=total_zknots[i], color = 'r', label='Actual')
            plt.legend(loc='best')
            plt.rcParams['figure.facecolor'] = 'white'
            plt.show()
```




Expected Overall Number of Z-knots in the Inkawasi Khipus
Number of Simulations
300
250
200
150
100
50
0
3500
4000
4500
5000
5500
6000
6500
Actual
Simulated
Number of Z-knots (Simulated, assuming equal, 50% probability of S and Z-knots)


Expected Overall Number of Z-knots in the All Khipus
Number of Simulations
250
200
150
100
50
0
17500
18000
18500
19000
19500
20000
20500
21000
Actual
Simulated
Number of Z-knots (Simulated, assuming equal, 50% probability of S and Z-knots)


Expected Overall Number of Z-knots in the Armatambo Khipus
Actual
Simulated
Number of Simulations
0
50
100
150
200
250
480
500
520
540
560
580
600
Number of Z-knots (Simulated, assuming equal, 50% probability of S and Z-knots)


Expected Overall Number of Z-knots in the Puruchuco Khipus
Actual
Simulated
Number of Simulations
0
50
100
150
200
250
350
400
450
500
550
600
Number of Z-knots (Simulated, assuming equal, 50% probability of S and Z-knots)

But what about parsing knot direction by knot type? Do different knot types favor particular knot directions? Note that the vast majority of single knots are tied as Z-knots, while long and figure-eight knots are tied as both S- and Z-knots.

```
In [8]: for i in index.keys():
            print i
            print "Total Single Knots:", \
                knot_direction_counts[i]['Single_S'].sum() \
                + knot_direction_counts[i]['Single_Z'].sum()
            print "Total Long/Figure-Eight Knots:", \
                (knot_direction_counts[i]['Long_S'].sum() \
                + knot_direction_counts[i]['Long_Z'].sum() \
                + knot_direction_counts[i]['E_S'].sum() \
                + knot_direction_counts[i]['E_Z'].sum())
            print
            print "Z Long Knots:", knot_direction_counts[i]['Long_Z'].sum()
            print "S Long Knots ", knot_direction_counts[i]['Long_S'].sum()
            print
            print "Z E Knots", knot_direction_counts[i]['E_Z'].sum()
            print "S E Knots", knot_direction_counts[i]['E_S'].sum()
            print
            print "Z Single Knots:", knot_direction_counts[i]['Single_Z'].sum()
            print "S Single Knots:", knot_direction_counts[i]['Single_S'].sum()
            print "Number of Khipus where Z/S Knots are recorded:", \
                len(knot_direction_counts[i][~(knot_direction_counts[i]==0).all(axis=1)])
            print '########################################################'
```

```
Pachacamac
Total Single Knots: 3367
Total Long/Figure-Eight Knots: 3063


Z Long Knots: 1271
S Long Knots  1189


Z E Knots 368
S E Knots 235
```

Z Single Knots: 3086

S Single Knots: 281

Number of Khipus where Z/S Knots are recorded: 73

###

Inkawasi

Total Single Knots: 4233

Total Long/Figure-Eight Knots: 3680

Z Long Knots: 1109

S Long Knots 1531

Z E Knots 886

S E Knots 154

Z Single Knots: 4214

S Single Knots: 19

Number of Khipus where Z/S Knots are recorded: 52

###

All

Total Single Knots: 13766

Total Long/Figure-Eight Knots: 22384

Z Long Knots: 8208

S Long Knots 8945

Z E Knots 3902

S E Knots 1329

Z Single Knots: 8579

S Single Knots: 5187

Number of Khipus where Z/S Knots are recorded: 316

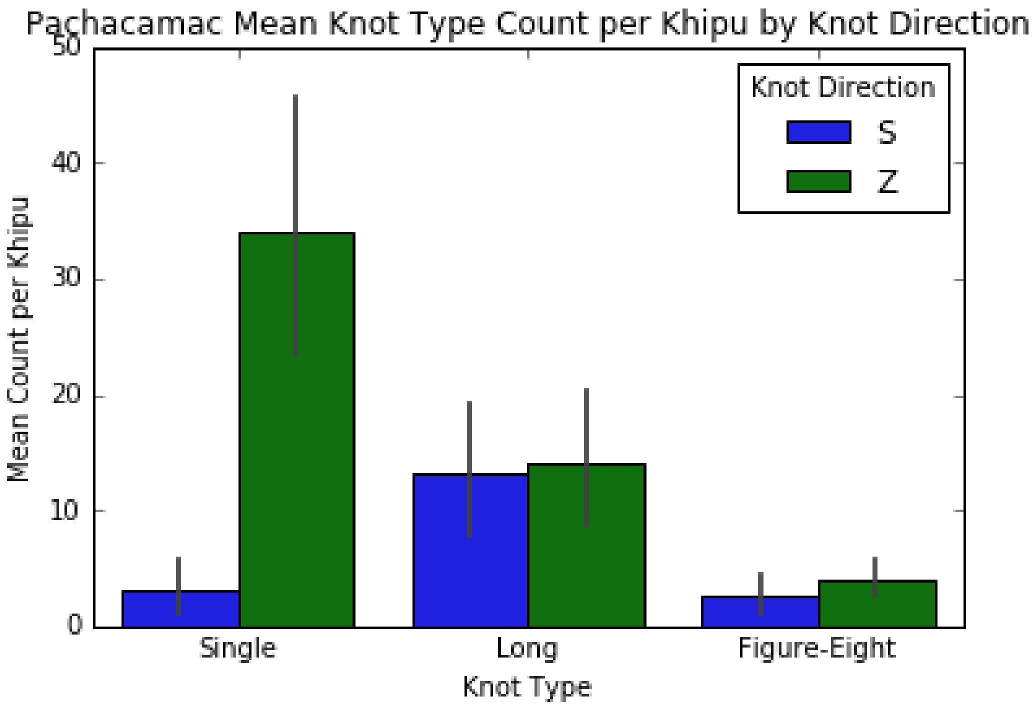
###

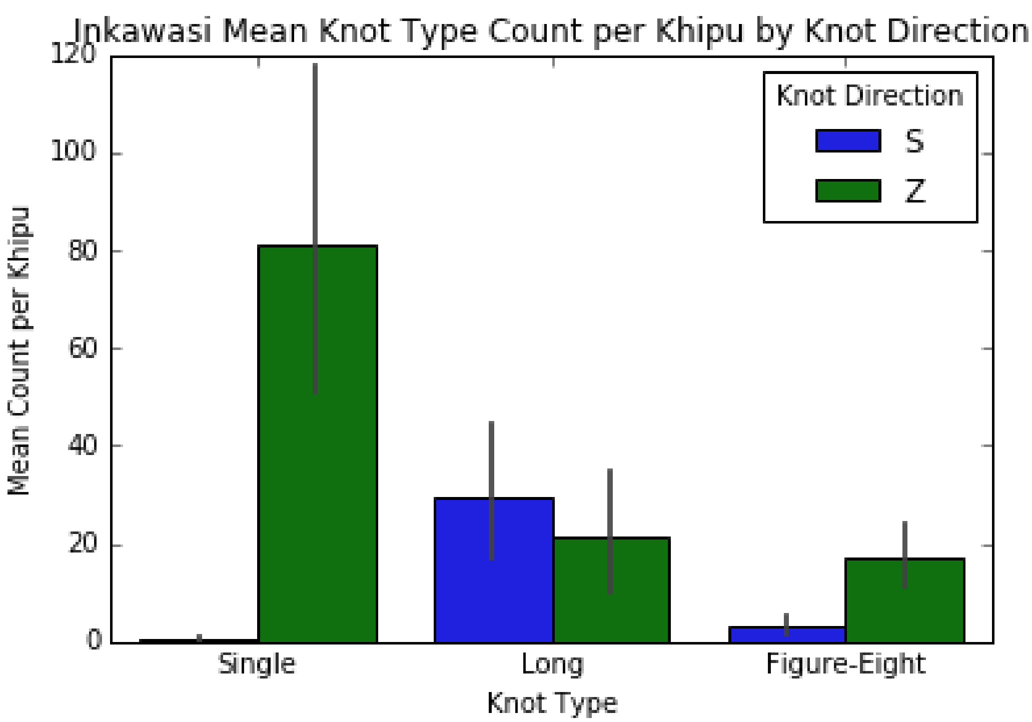
Armatambo

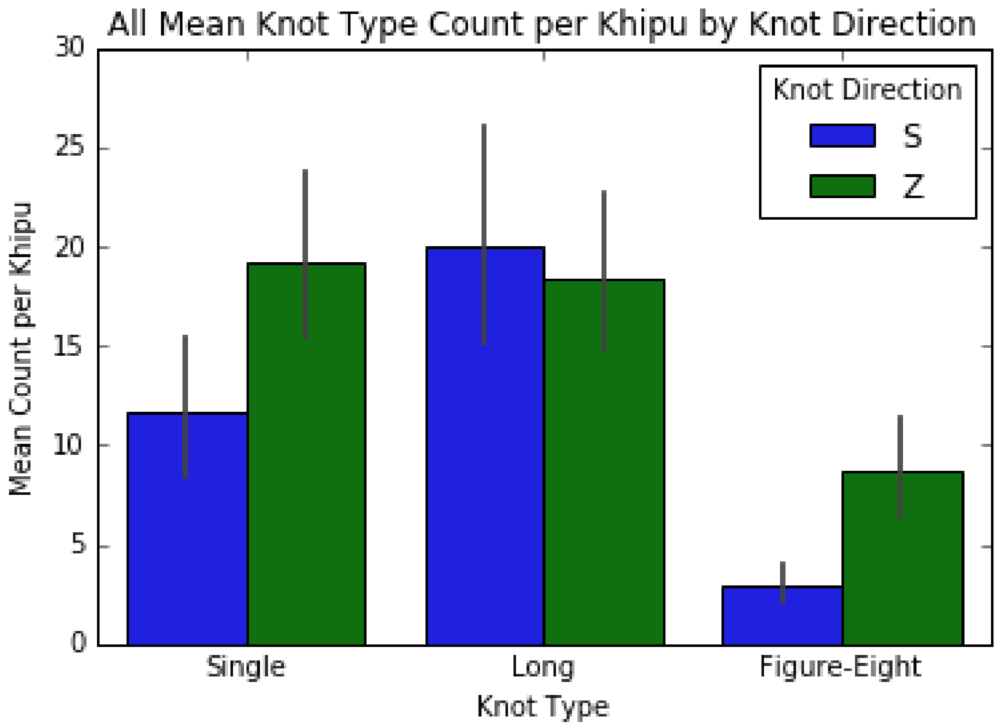
Total Single Knots: 456

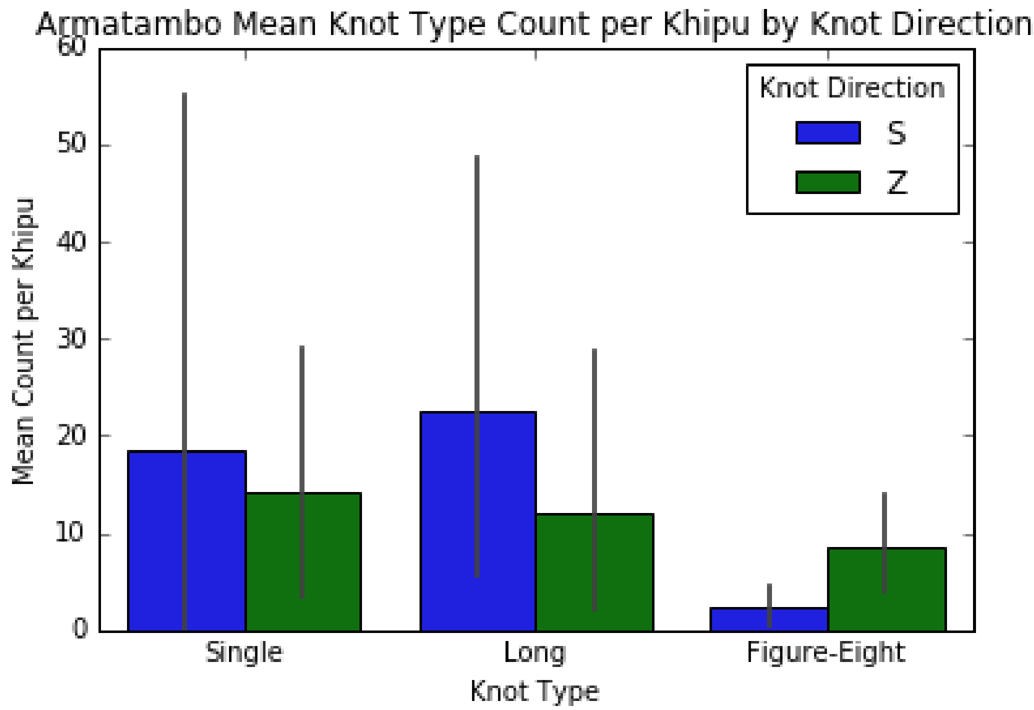
```
Total Long/Figure-Eight Knots: 637

Z Long Knots: 167
S Long Knots  315

Z E Knots 121
S E Knots 34

Z Single Knots: 197
S Single Knots: 259
Number of Khipus where Z/S Knots are recorded: 14
#######################################################
Puruchuco
Total Single Knots: 204
Total Long/Figure-Eight Knots: 612

Z Long Knots: 357
S Long Knots  5

Z E Knots 27
S E Knots 223

Z Single Knots: 191
S Single Knots: 13
Number of Khipus where Z/S Knots are recorded: 20
#######################################################
```

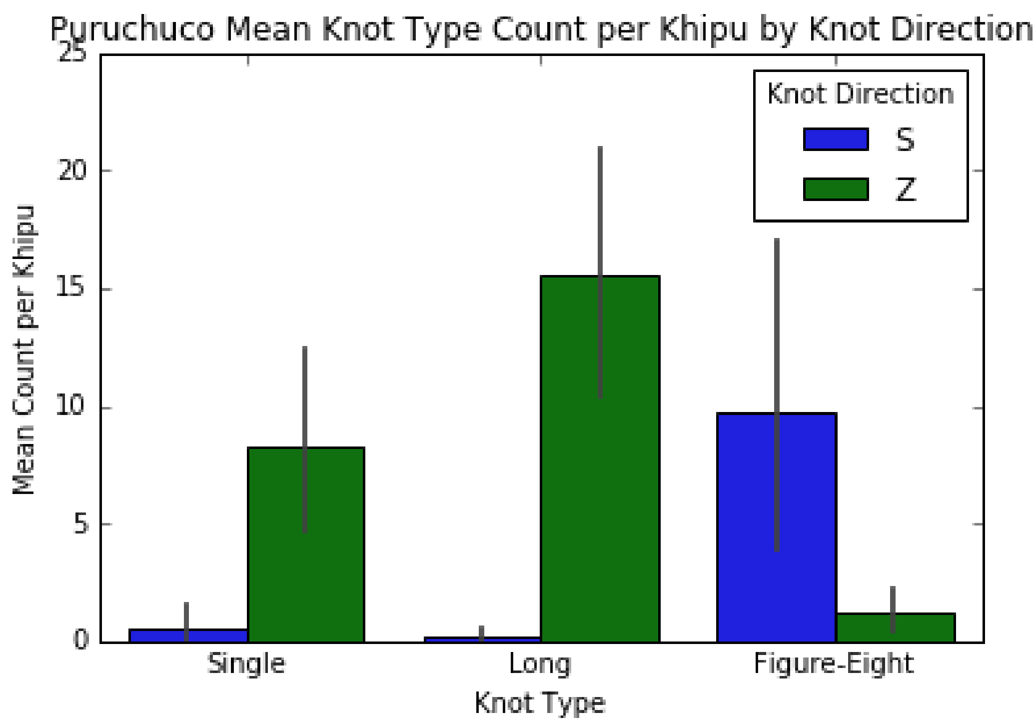
```
In [9]: for i in index.keys():
            df = pd.melt(knot_direction_counts[i])
            df["Knot Direction"] = df.variable.str[-1]
            df["Knot Type"] = df.variable.str.replace('_S', '').str.replace('_Z', '')
            sns.barplot(x="Knot Type", y="value", hue="Knot Direction", data=df)
            plt.ylabel('Mean Count per Khipu')
            plt.xticks([0,1,2],['Single','Long','Figure-Eight'])
            plt.title('%s Mean Knot Type Count per Khipu by Knot Direction' % i)
            plt.show();
```


Pachacamac Mean Knot Type Count per Khipu by Knot Direction
Knot Direction
S
Z
Mean Count per Khipu
0
10
20
30
40
50
Single
Long
Figure-Eight
Knot Type


Inkawasi Mean Knot Type Count per Khipu by Knot Direction
Knot Direction
S
Z
Mean Count per Khipu
0
20
40
60
80
100
120
Single
Long
Figure-Eight
Knot Type


All Mean Knot Type Count per Khipu by Knot Direction
Knot Direction
S
Z
Mean Count per Khipu
0
5
10
15
20
25
30
Single
Long
Figure-Eight
Knot Type


Armatambo Mean Knot Type Count per Khipu by Knot Direction
Mean Count per Khipu
0
10
20
30
40
50
60
Knot Direction
S
Z
Single
Long
Figure-Eight
Knot Type


Puruchuco Mean Knot Type Count per Khipu by Knot Direction
Mean Count per Khipu
0
5
10
15
20
25
Knot Direction
S
Z
Single
Long
Figure-Eight
Knot Type

To further examine the use of S and Z-knot types by knot-type, I then looked at the frequencies of each knot type occurring as a Z or S-knot, using the `count_SZ_alone()` function:

```
In [10]: def count_SZ_alone(khipu_index, khipu_folder_path):
             count_S_LE_Alone_l, count_Z_LE_Alone_l, count_S_Single_Alone_l, \
                 count_Z_Single_Alone_l = [[] for _ in range(4)]
             Single_S, Single_Z, Long_S, Long_Z, E_S, E_Z = [[] for _ in range(6)]
             for i in khipu_index:
                 df = pd.read_excel('%s\Khipu_%s.xlsx' % \
                          (khipu_folder_path,i), parse_cols = range(5,14))
                 count_S_LE_Alone, count_Z_LE_Alone, count_S_Single_Alone, \
                         count_Z_Single_Alone= [0 for _ in range(4)]
                 for i in df.iterrows():
                     count_Single_S, count_Single_Z, count_Long_S, count_Long_Z, \
                             count_E_S, count_E_Z = [0 for _ in range(6)]
                     if i[1].astype(str).str.contains('/S').any():
                         count_Long_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/S)')])
                         count_E_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/S)')])
                         count_Single_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/S)')])
                     if i[1].astype(str).str.contains('Z').any():
                         count_Long_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/Z)')])
                         count_E_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/Z)')])
                         count_Single_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/Z)')])

                     #Count L/E knots that don't have single knots on the same cord as Z & S:
                     if (count_E_Z != 0 or count_Long_Z != 0) and \
                             (count_Single_S == 0 and count_Single_Z == 0):
                         count_Z_LE_Alone += 1
                     if (count_E_S != 0 or count_Long_S != 0) and \
                             (count_Single_S == 0 and count_Single_Z == 0):
```

```
                    count_S_LE_Alone += 1

                #Count Single knots that are alone (free of L/E knots below) as Z and S:
                if (count_Long_Z == 0 and count_E_Z == 0) and (count_Single_S != 0):
                    count_S_Single_Alone += 1
                if (count_Long_S == 0 and count_E_S == 0) and (count_Single_Z != 0):
                    count_Z_Single_Alone += 1

            count_S_LE_Alone_l.append(count_S_LE_Alone)
            count_Z_LE_Alone_l.append(count_Z_LE_Alone)
            count_S_Single_Alone_l.append(count_S_Single_Alone)
            count_Z_Single_Alone_l.append(count_Z_Single_Alone)
        return count_S_LE_Alone_l, count_Z_LE_Alone_l, count_S_Single_Alone_l, \
            count_Z_Single_Alone_l
```

```
In [11]: count_S_LE_Alone_l = {}; count_Z_LE_Alone_l = {}; count_S_Single_Alone_l = {}
         count_Z_Single_Alone_l = {}

         for i in index.keys():
             count_S_LE_Alone_l[i], count_Z_LE_Alone_l[i], count_S_Single_Alone_l[i], \
                 count_Z_Single_Alone_l[i] = \
                         count_SZ_alone(index[i], 'Data\Individual_All_Khipus')
```

When the knots are alone on a cord, I found that the ratio of S:Z knots is greater for long and figure-eight knots than it is for single knots (everywhere but Armatambo). That being said, below, I still see more Z long and figure-eight knots than I do S long and figure-eight knots (everywhere but Pachacamac and Puruchuco). S-knots seem to have been used more often for these types of knots than for single knots, but there are still a good number of Z knots present. Why is there this muddiness for lower hierarchy knots and not for higher hierarchy knots?

Again, however, note the clear effect at the single knot level: these Z single knot counts are highly unlikely to occur by chance alone at the single knot level (everywhere but Armatambo, where S knots are significantly more likely at the single knot level).

```
In [12]: for i in count_S_LE_Alone_l:
             print i
             print "S Long/Figure Eight Knots (alone):", sum(count_S_LE_Alone_l[i])
```

```
            print "Z Long/Figure Eight Knots (alone):", sum(count_Z_LE_Alone_l[i])
            print "Binomial Test p-value (two-sided):", \
                stats.binom_test([sum(count_S_LE_Alone_l[i]), \
                sum(count_Z_LE_Alone_l[i])], alternative='two-sided')
            print
            print "S Single Knots (alone):", sum(count_S_Single_Alone_l[i])
            print "Z Single Knots (alone):", sum(count_Z_Single_Alone_l[i])
            print "Binomial Test p-value (one-sided):", \
                stats.binom_test([sum(count_Z_Single_Alone_l[i]), \
                sum(count_S_Single_Alone_l[i])], alternative='greater')
            print '############################################################'
```

```
Pachacamac
S Long/Figure Eight Knots (alone): 641
Z Long/Figure Eight Knots (alone): 639
Binomial Test p-value (two-sided): 0.977702803892638

S Single Knots (alone): 182
Z Single Knots (alone): 1659
Binomial Test p-value (one-sided): 1.7919515272797957e-298
############################################################
Inkawasi
S Long/Figure Eight Knots (alone): 402
Z Long/Figure Eight Knots (alone): 835
Binomial Test p-value (two-sided): 2.2313415358218515e-35

S Single Knots (alone): 19
Z Single Knots (alone): 1619
Binomial Test p-value (one-sided): 0.0
############################################################
All
S Long/Figure Eight Knots (alone): 5256
Z Long/Figure Eight Knots (alone): 7200
Binomial Test p-value (two-sided): 3.764840021907389e-68

S Single Knots (alone): 3679
Z Single Knots (alone): 5979
```

```
Binomial Test p-value (one-sided): 1.7674261986949726e-122
############################################################
Armatambo
S Long/Figure Eight Knots (alone): 165
Z Long/Figure Eight Knots (alone): 227
Binomial Test p-value (two-sided): 0.0020247624042250504

S Single Knots (alone): 187
Z Single Knots (alone): 145
Binomial Test p-value (one-sided): 0.9909276821092292
############################################################
Puruchuco
S Long/Figure Eight Knots (alone): 217
Z Long/Figure Eight Knots (alone): 251
Binomial Test p-value (two-sided): 0.1270631827397873

S Single Knots (alone): 2
Z Single Knots (alone): 139
Binomial Test p-value (one-sided): 3.5916288575539395e-39
############################################################
```

Do the knot directions relate to one another in a consistent marked/unmarked fashion, however? Given the large observable difference between single knots and long/figure-eight knots in S vs. Z knot direction frequency, it seems that knot direction might have been used as a sign for marking higher hierarchical positions on a cord in relation to lower ones–following a markedness relationship. If this were the case, we might expect cords that have single knots tied in a Z direction to have had the long/figure-eight knot tied in an S-direction, to mark the lower hierarchy knots as distinct from the higher hierarchy knots.

As noted in the Chapter 3 in-text discussion, I similarly expect there to be a large number of khipu cords that have both single and long/figure-eight knots tied in the Z-direction because marked categories tend to be absorbed by unmarked categories (I would not, however, expect there to be many khipu cords with all knot types tied in the S-direction, or single knots tied in the S direction and long/figure-eight knots tied in the Z direction; see in-text discussion in Chapter 3). I adjusted the `count_SZ` function a bit below to see whether or not the evidence supports such a theory. I called the new function `count_sz_multi` to recognize that it's looking for relationships between multiple entries on a single cord and counting the number of times each relationship occurs.

```
In [13]: def count_SZ_multi(khipu_index, khipu_folder_path):
             Multi_S, Multi_Z, Multi_S_Single_S, Multi_S_Single_Z = [[] for _ in range(4)]
             Single_S, Single_Z, Long_S, Long_Z, E_S, E_Z = [[] for _ in range(6)]
             for i in khipu_index:
                 df = pd.read_excel('%s\Khipu_%s.xlsx' % (khipu_folder_path,i), parse_cols \
                     = range(5,14))
                 count_S_Multi,count_Z_Multi,count_S_Multi_Single_S,count_S_Multi_Single_Z\
                     = [0 for _ in range(4)]
                 for i in df.iterrows():
                     count_Single_S, count_Single_Z, count_Long_S, count_Long_Z, count_E_S, \
                         count_E_Z = [0 for _ in range(6)]
                     if i[1].astype(str).str.contains('/S').any():
                         count_Long_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/S)')])
                         count_E_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/S)')])
                         count_Single_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/S)')])
                     if i[1].astype(str).str.contains('Z').any():
                         count_Long_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/Z)')])
                         count_E_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/Z)')])
                         count_Single_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/Z)')])

                     #Count cords where Long/Figure-8 Z-knots co-occur with Single S/Z-knots
                     if (count_Long_Z != 0 or count_E_Z != 0) and (count_Single_S != 0):
                         count_S_Multi += 1
                     if (count_Long_Z != 0 or count_E_Z != 0) and (count_Single_Z != 0):
                         count_Z_Multi += 1

                     # Count number of cords where Long/Figure-8 S-knots co-occur with Single
```

```
S/Z-knots

            if (count_Long_S != 0 or count_E_S != 0) and (count_Single_S != 0):
                count_S_Multi_Single_S += 1
            if (count_Long_S != 0 or count_E_S != 0) and (count_Single_Z != 0):
                count_S_Multi_Single_Z += 1

        Multi_S.append(count_S_Multi), Multi_Z.append(count_Z_Multi),
        Multi_S_Single_Z.append(count_S_Multi_Single_Z),
        Multi_S_Single_S.append(count_S_Multi_Single_S)
    return Multi_S, Multi_Z, Multi_S_Single_Z, Multi_S_Single_S
```

```
In [14]: Multi_S = {}; Multi_Z = {}; Multi_S_Single_Z = {}; Multi_S_Single_S = {}

         for i in index.keys():
             Multi_S[i], Multi_Z[i], Multi_S_Single_Z[i], Multi_S_Single_S[i] = \
                 count_SZ_multi(index[i], 'Data\Individual_All_Khipus')
```

Note below that there are a statistically significant number of Long or Figure-Eight knots tied in the S-direction when Single knots are tied in the Z-direction overall (except for Puruchuco, where there is a small sample size and no clear distinction between these cord categories, and Armatambo). Similarly, there are a statistically significant number of Long/Figure-eight knots tied in the Z-direction when Single knots are tied in the Z-direction overall. Interestingly, overall, we also see that when single knots are tied in the Z-direction, they tend to be accompanied more often than not by an S-tied long or figure-eight knot ($p<0.0001$). All of these findings are consistent with the theory of knot direction markedness proposed in Chapter 3 (except for the khipus from Armatambo; see in-text discussion).

```
In [15]: for i in index.keys():
             print i
             print "Long/Figure-Eight Z, Single S:", sum(Multi_S[i]), \
                     ", Long/Figure-Eight S, Single Z:", sum(Multi_S_Single_Z[i])
             print "Binomial Test p-value (one-sided):", \
                 stats.binom_test([sum(Multi_S_Single_Z[i]), sum(Multi_S[i])], \
                         alternative='greater')
             print
             print "Long/Figure-Eight S, Single S:", sum(Multi_S_Single_S[i]), \
                     ", Long/Figure-Eight Z , Single Z:", sum(Multi_Z[i])
```

```
        print "Binomial Test p-value (one-sided):", stats.binom_test([sum(Multi_Z[i]), \
            sum(Multi_S_Single_S[i])], alternative='greater')
        print '######################################################################'
```

```
Pachacamac
Long/Figure-Eight Z, Single S: 13 , Long/Figure-Eight S, Single Z: 565
Binomial Test p-value (one-sided): 1.1654195219110352e-148

Long/Figure-Eight S, Single S: 165 , Long/Figure-Eight Z, Single Z: 910
Binomial Test p-value (one-sided): 1.4424156384801725e-125
######################################################################
Inkawasi
Long/Figure-Eight Z, Single S: 0 , Long/Figure-Eight S, Single Z: 1212
Binomial Test p-value (one-sided): 0.0

Long/Figure-Eight S, Single S: 13 , Long/Figure-Eight Z, Single Z: 987
Binomial Test p-value (one-sided): 1.404278825920082e-272
######################################################################
All
Long/Figure-Eight Z, Single S: 373 , Long/Figure-Eight S, Single Z: 715
Binomial Test p-value (one-sided): 9.529430908401922e-26

Long/Figure-Eight S, Single S: 2603 , Long/Figure-Eight Z, Single Z: 3728
Binomial Test p-value (one-sided): 7.684200367266776e-46
######################################################################
Armatambo
Long/Figure-Eight Z, Single S: 0 , Long/Figure-Eight S, Single Z: 29
Binomial Test p-value (one-sided): 1.862645149230957e-09

Long/Figure-Eight S, Single S: 152 , Long/Figure-Eight Z, Single Z: 43
Binomial Test p-value (one-sided): 0.9999999999999998
######################################################################
Puruchuco
Long/Figure-Eight Z, Single S: 8 , Long/Figure-Eight S, Single Z: 10
Binomial Test p-value (one-sided): 0.40726470947265614
```

```
Long/Figure-Eight S, Single S: 0 , Long/Figure-Eight Z, Single Z: 113
Binomial Test p-value (one-sided): 9.629649721936178e-35
####################################################################
```

Finally, I counted the number of times single knots co-occurred in both the S and Z-directions on the same cord (to see if there was any potential markedness behavior occurring within the single-knot knot type itself). There were very few instances where this occurred, so I argued that the markedness relationship was primarily signified between the Single and Long/Figure-eight knot types and not within the Single-knot knot type itself.

```
In [16]: def count_Single_SZ_multi(khipu_index, khipu_file_path):
             Multi_SZ = []
             Single_S, Single_Z, Long_S, Long_Z, E_S, E_Z = [[] for _ in range(6)]
             total_count = 0
             for i in khipu_index:
                 df = pd.read_excel('%s\Khipu_%s.xlsx' % (khipu_file_path,i), parse_cols = \
                         range(5,14))
                 count_SZ_Multi = 0
                 for i in df.iterrows():
                     count_Single_S, count_Single_Z, count_Long_S, count_Long_Z, count_E_S, \
                         count_E_Z = [0 for _ in range(6)]
                     if i[1].astype(str).str.contains('/S').any():
                         count_Long_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/S)')])
                         count_E_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/S)')])
                         count_Single_S += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/S)')])
                     if i[1].astype(str).str.contains('Z').any():
                         count_Long_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*L)(?=.*/Z)')])
                         count_E_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*E)(?=.*/Z)')])
                         count_Single_Z += \
                             len(i[1][i[1].astype(str).str.contains(r'(?=.*S/)(?=.*/Z)')])

                     if (count_Single_Z != 0) and (count_Single_S != 0):
                         count_SZ_Multi += 1
```

```
                    total_count += 1
                Multi_SZ.append(count_SZ_Multi)

            return Multi_SZ, total_count
```

```
In [17]: Multi_SZ = {}; total_count = {}

         for i in index.keys():
             Multi_SZ[i], total_count[i] = count_Single_SZ_multi(index[i], \
                 'Data\Individual_All_Khipus')
```

```
In [18]: for i in index.keys():
             print i
             print "Number of times single knots co-occur in both S and Z directions:",
         sum(Multi_SZ[i])
             print "Number of total analyzed cords in the %s Khipus:" % i, total_count[i]
             print '##########################################################################'
```

```
Pachacamac
Number of times single knots co-occur in both S and Z directions: 5
Number of total analyzed cords in the Pachacamac Khipus: 5971
##########################################################################
Inkawasi
Number of times single knots co-occur in both S and Z directions: 4
Number of total analyzed cords in the Inkawasi Khipus: 5708
##########################################################################
All
Number of times single knots co-occur in both S and Z directions: 30
Number of total analyzed cords in the All Khipus: 43062
##########################################################################
Armatambo
Number of times single knots co-occur in both S and Z directions: 0
Number of total analyzed cords in the Armatambo Khipus: 954
##########################################################################
Puruchuco
Number of times single knots co-occur in both S and Z directions: 0
Number of total analyzed cords in the Puruchuco Khipus: 985
##########################################################################
```

A.2 Chapter 4 Supplementary Code

First, I loaded all the packages I needed to perform my analysis:

```
In [1]: %matplotlib inline
        import numpy as np # Version 1.14.5
        import pandas as pd # Version 0.22.0
        import statsmodels.api as sm # Version 0.9.0
        import statsmodels.stats.api as sms
        import scipy.stats as stats # Version 1.1.0
        import seaborn as sns # Version 0.9.0
        import matplotlib.pyplot as plt # Version 1.5.1
        from statsmodels.stats.multicomp import pairwise_tukeyhsd # Version 0.9.0
        from statsmodels.stats.multicomp import MultiComparison
        import re
        from khipu_functions import BrezineColorConverter
```

Then, I read in pre-wrangled KDB khipu data from CSV (available as supplemental online material for the dissertation on DASH, Harvard's open-access online repository: https://dash.harvard.edu/) to pandas dataframes.

```
In [2]: summaries = pd.read_csv('Data/Geo_Khipu_Data_8_1_2018.csv')
        cords = pd.read_csv('Data/Master_Cord_Data_8_1_2018.csv')
```

To begin my analysis, I wanted to look at the Inkawasi khipus cords to determine whether pendant cords were more often light or dark colors. To define colors as dark or light, I converted all colors to the Brezine scheme of colors (see in-text discussion in Chapter 4, and function `BrezineColorConverter()` in the `khipu_functions.py` file on DASH as well as in Appendix A.4), collapsing similar colors into single color categories based on their relative position in comparison to white and black–light and dark. The scheme makes it possible to compare similar colors across observers (accounting for inter-observer error in the database), as well as take into account the relative lightness and darkness of a color (how close to white or black they might be).

In the Brezine Scheme, first, colors are organized from top to bottom by hue, as per a standard color diagram. Then, compound colors are placed below these hues in terms of how much black they integrate. In the Left to Right direction the scheme accounts for the shade of each one of the colors (i.e. more or less black/white within the given hue). Thus, from the upper left corner of the diagram to the lower right, the colors gradually transition light to dark. Below, I created a 10-point scale that assigns a score to each color based on how close that color is to white or black respectively in the Brezine Scheme (0 being closest to white and 10 being closest to black, with 5 being in the brown color range). I additionally scored the colors in color combination cords (called `tinku` in the code, since they are the coming together of two opposing colors, as discussed in Chapter 4) in terms of their lightest and darkest components as a way of getting after culturally specific interpretations of light and dark (see in-text discussion in Chapter 4).

```
In [3]: incahuasi_summaries = summaries[summaries['Provenance_CLEAN'] == 'Incahuasi']
        incahuasi_cords = cords[cords.Khipu.isin(incahuasi_summaries.Khipu)]
        incahuasi_cords = BrezineColorConverter(incahuasi_cords)
```

```
In [4]: # Score colors on a 10-point scale: White=0 to Black=10
        score_dict = {
            #Spread evenly from 0-5, means intervals of .555
            'A': 0,
            'R': .555,
            'N': 1.11,
            'Y': 1.67,
            'G': 2.22,
            'H': 2.78,
            'B': 3.33,
            'L': 3.89,
            'M': 4.44,
            'Z': 5
        }

        scored_colors_all =
        pd.Series(incahuasi_cords.Brezine_Colors[incahuasi_cords['Brezine_Colors'] != \
                ''']).str.split("[^a-zA-Z0-9]") \
            .apply(lambda x: [score_dict[color[0]] + float(color[1]) for color in x \
                if color[0] in score_dict])

        avg_light = scored_colors_all.apply(lambda x: np.mean(x))
```

```
# Separate solid color cords and tinku cords
solids = scored_colors_all[[len(i) == 1 for i in scored_colors_all]]
solids = [i[0] for i in solids]

tinkus = scored_colors_all[[len(i) > 1 for i in scored_colors_all]]
tinkus_dark = [np.max(i) for i in tinkus]
tinkus_light = [np.min(i) for i in tinkus]
tinkus_avg = [np.average(i) for i in tinkus]

print "Frequency of Solid to Color Combo Cords: (Inkawasi)",len(solids)," to ",\
        len(tinkus), " or ", np.float(len(solids))/np.float(len(tinkus))
print "Probability of larger Solid Color count: (Inkawasi)", \
stats.binom_test([len(solids), len(tinkus)], alternative='greater')
```

```
Frequency of Solid to Color Combo Cords: (Inkawasi) 4728  to  921  or
5.1335504886
Probability of larger Solid Color count: (Inkawasi) 0.0
```

I then compared the mean solid color darkness score with the darkest and lightest colors within each color combination cord via ANOVA to see if there was a statistically significant difference between the color darkness scores

```
In [5]: print np.average(solids), np.average(tinkus_dark), np.average(tinkus_light)
        print stats.f_oneway(solids, tinkus_dark, tinkus_light)
```

```
4.799263959390863 6.3471878393051036 3.6807003257328987
F_onewayResult(statistic=395.89003734650527, pvalue=4.6523856253294055e-163)
```

There is a statistically significant difference between the scores, so I compared the mean differences between solid color scores and both darkest and lightest color scores within each color combination cord. I computed a 95% confidence interval for each mean difference, so that I could tell whether or not there was a statistically significant difference (at the 0.05 level) between the two mean differences.

I made these comparisons in order to determine whether the mean solid darkness score is closest to the lightest component of the color combination cords (a proxy for “light” colors for this analysis; see discussion in Chapter 4) or the darkest component of color combination cords (a proxy of "dark" colors for this analysis). Note that solid cords at Inkawasi are closer to the lightest component (the absolute mean difference is smaller and there is a statistically significant difference between the two mean differences) than the dark component, consistent with the notion that dark color solid cords are associated with marked categories and light color solid cords are associated with unmarked categories.

```
In [6]: df_solid = pd.DataFrame([pd.Series(solids), pd.Series(np.repeat('Solid', \
          len(solids)))]).T
        df_dark = pd.DataFrame([pd.Series(tinkus_dark), pd.Series(np.repeat('Tinku_Dark', \
          len(tinkus_dark)))]).T
        df_light = pd.DataFrame([pd.Series(tinkus_light), pd.Series(np.repeat('Tinku_Light',\
          len(tinkus_light)))]).T

          #Bonferroni Correction on CIs due to multiple comparisons (.05/2):
          cm = sms.CompareMeans(sms.DescrStatsW(tinkus_dark), sms.DescrStatsW(solids))
          print "95% CI For Difference Between Solid Color Score and Darkest Color (in a \
                  color combo cord) Score: "
          print cm.tconfint_diff(alpha=.025, usevar='unequal')
          print cm
          cm1 = sms.CompareMeans(sms.DescrStatsW(tinkus_light), sms.DescrStatsW(solids))
          print "95% CI For Difference Between Solid Color Score and Lightest Color (in a \
                  color combo cord) Score: "
          print cm1.tconfint_diff(alpha=.025, usevar='unequal')
```

```
95% CI For Difference Between Solid Color Score and Darkest Color (in a
color combo cord) Score:
(1.457770983604194, 1.6380767762242825)
<statsmodels.stats.weightstats.CompareMeans object at 0x0000000010B69CF8>
95% CI For Difference Between Solid Color Score and Lightest Color (in a
color combo cord) Score:
(-1.2954524021657348, -0.9416748651501983)
```

If we perform the same analysis globally across the khipus in the KDB (below), we observe the same effect (at 94% CIs), indicating that dark color solid cords are consistent with marked categories, and light color solid cords are consistent with unmarked categories.

```
In [7]: cords = BrezineColorConverter(cords)
        color_counts_global = cords['Brezine_Colors'].value_counts()

          #Drop color counts for cords where no color was recorded:
          color_counts_global = color_counts_global[color_counts_global.index.values != '']

          scored_colors_all = pd.Series(cords.Brezine_Colors[cords['Brezine_Colors'] != \
                  '']).str.split("[^a-zA-Z0-9]") \
              .apply(lambda x: [score_dict[color[0]] + float(color[1]) for color in x \
                          if color[0] in score_dict])

          avg_light = scored_colors_all.apply(lambda x: np.mean(x))

          #Separate solid color cords and tinku cords
          solids = scored_colors_all[[len(i) == 1 for i in scored_colors_all]]
          solids = [i[0] for i in solids]

          tinkus = scored_colors_all[[len(i) > 1 for i in scored_colors_all]]
          tinkus_dark = [np.max(i) for i in tinkus]
          tinkus_light = [np.min(i) for i in tinkus]
          tinkus_avg = [np.average(i) for i in tinkus]

          print "Frequency of Solid to Color Combo Cords (KDB): ", len(solids), " to ", \
                  len(tinkus), " or ", np.float(len(solids))/np.float(len(tinkus))
          print "Probability of larger Solid Color count (KDB):", \
                   stats.binom_test([len(solids), len(tinkus)], alternative='greater')

          # Now perform multiple comparisons:
          df_solid = pd.DataFrame([pd.Series(solids), pd.Series(np.repeat('Solid', \
                  len(solids)))]).T
          df_dark = pd.DataFrame([pd.Series(tinkus_dark), pd.Series(np.repeat( \
                  'Tinku_Dark', len(tinkus_dark)))]).T
          df_light = pd.DataFrame([pd.Series(tinkus_light), pd.Series(np.repeat( \
                  'Tinku_Light', len(tinkus_light)))]).T

          #Bonferroni Correction on CIs due to multiple comparisons (.06/2):
          cm = sms.CompareMeans(sms.DescrStatsW(tinkus_dark), sms.DescrStatsW(solids))
          print "94% CI For Difference Between Solid Color Score and Darkest Color (in a
                  color combo cord) Score: "
          print cm.tconfint_diff(alpha=.03, usevar='unequal')
```

```
    print
    cm1 = sms.CompareMeans(sms.DescrStatsW(tinkus_light), sms.DescrStatsW(solids))
    print "94% CI For Difference Between Solid Color Score and Lightest Color (in a
        color combo cord) Score: "
    print cm1.tconfint_diff(alpha=.03, usevar='unequal')
```

```
Frequency of Solid to Color Combination Cords (KDB):  40266  to  14668  or
2.74515953095
Probability of larger Solid Color count (KDB): 0.0
94% CI For Difference Between Solid Color Score and Darkest Color (in a
color combo cord) Score:
(1.9416956636408802, 2.0083069367716124)

94% CI For Difference Between Solid Color Score and Lightest Color (in a
color combo cord) Score:
(-1.9394108743931564, -1.842916767899568)
```

With a rough idea of how darkness seemed to have worked as an indicator of markedness, I then looked into the specifics of the different color combination types to see if there was any evidence to suggest how markedness relations might have been ordered according to these different types (see Chapter 4 in-text discussion). For instance, did Mottled cords signify unmarked categories and Barber Pole signify marked? How about color change cords?

To answer these questions, I first wrote a function to identify the type of color combination on each khipu cord. I used the function to identify the color combination type for every khipu cord both at Inkawasi and then globally in the KDB as a whole:

```
In [8]: incahuasi_cords = incahuasi_cords[incahuasi_cords.Colors.notnull()]
        cords = cords[cords.Colors.notnull()]

        def Color_Combo_Type_Identifier(cords_dataframe):
            '''
            Identifies whether each cord in a "cords" dataframe is Solid, Mottled,
            Barberpole, or Both. Adds these identifiers as a column in the dataframe
            and returns the dataframe without cords that have NaN values. Also identifies
```

```
the various types of color-change cords and adds a column for these designations.
'''
combo_types = []
color_change = []
cords_dataframe = cords_dataframe[cords_dataframe.Colors.notnull()]

#First account for cords that have color changes mid-cord and assess what kind of
#color-change cord they are:
for cord in cords_dataframe.Colors:
    if '\r\n' in cord:
        #Need to replace (0-0) position marker, as it confuses the function into
        #identifying false barber poles
        split_type = cord.split("^:-")[0].replace('(0-0)','')
        if len([x for x in split_type if x in ':']) >= 2:
            color_change.append("Multiple_Mottled")
        elif len([x for x in split_type if x in "-"]) >= 2:
            color_change.append("Multiple_Barberpole")
        elif ":" in split_type and "-" in split_type:
            color_change.append("Mottled_and_Barberpole")
        elif ":" in split_type:
            color_change.append("Mottled_and_Solid")
        elif "-" in split_type:
            color_change.append("Barberpole_and_Solid")
        else:
            color_change.append("Solid")
    else:
        color_change.append('None')

#Check to see if individ. cords contain characteristics of mottled/barberpole:
for cord in cords_dataframe.Colors:
    if '\r\n' not in cord:
        color_combo_type = cord.split("^:-")[0]
        if ":" in color_combo_type and "-" in color_combo_type:
            combo_types.append("Both")
        elif ":" in color_combo_type:
            combo_types.append("Mottled")
        elif "-" in color_combo_type:
            combo_types.append("Barberpole")
        elif ":" or "-" not in color_combo_type:
            combo_types.append("Solid")
```

```
            else:
                combo_types.append("Color-Change")

        combo_types_series = pd.Series(combo_types).values
        color_change_series = pd.Series(color_change).values
        cords_dataframe.insert(loc=10,column='Combination_Type',value=combo_types_series)
        cords_dataframe.insert(loc=11, column='Color_Change', value=color_change_series)

        return cords_dataframe

    incahuasi_color_combos_all = Color_Combo_Type_Identifier(incahuasi_cords)
    global_color_combos_all = Color_Combo_Type_Identifier(cords)
```

Below, printing out frequencies of each color combination type, we can see that mottled cords are much more common than barberpole, both globally in the database as well as locally at Inkawasi. We might infer then that the markedness relationship worked as follows: Solid light > Mottled > Barberpole > Solid dark.

```
In [9]: # First, let's only look at the fundamental color combination types: Light, Dark,
        # Mottled, BP, removing the color-change cords:
        incahuasi_color_combos = \
          incahuasi_color_combos_all[~incahuasi_color_combos_all.Colors.str.contains('\r\n')]
        global_color_combos = \
          global_color_combos_all[~global_color_combos_all.Colors.str.contains('\r\n')]

        print "Global Solid: ",len(global_color_combos[global_color_combos.Combination_Type \
                == 'Solid'])
        print "Global Mottled: ", len(global_color_combos[global_color_combos \
                .Combination_Type == 'Mottled'])
        print "Global Barberpole: ", \
                len(global_color_combos[global_color_combos.Combination_Type == 'Barberpole'])
        print "Mottled to Barberpole: ",
                float(len(global_color_combos[global_color_combos.Combination_Type ==  \
                'Mottled']))/float(  \
            len(global_color_combos[global_color_combos.Combination_Type == 'Barberpole']))
        print "Probability of larger Mottled count:", \
            stats.binom_test([len(global_color_combos[ \
            global_color_combos.Combination_Type == 'Mottled']),
            len(global_color_combos[global_color_combos.Combination_Type=='Barberpole'])],\
```

```
            alternative='greater')
        print "Global Both: ", len(global_color_combos[global_color_combos.Combination_Type \
                == 'Both'])
        print "--------------------------------"
        print "Inkawasi Solid:" \
            len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type == 'Solid'])
        print "Inkawasi Mottled: ", \
            len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type == 'Mottled'])
        print "Inkawasi Barberpole: ", \
            len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type=='Barberpole'])
        print "Mottled to Barberpole: ", \
            float(len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type \
            == 'Mottled']))/float( \
            len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type == \
            'Barberpole']))
        print "Probability of larger Mottled count:", \
        stats.binom_test([len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type \
        == 'Mottled']), \
        len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type \
        == 'Barberpole'])], alternative='greater')
        print "Inkawasi Both: ",
        len(incahuasi_color_combos[incahuasi_color_combos.Combination_Type == 'Both'])
```

```
Global Solid:  40724
Global Mottled:  9851
Global Barberpole:  2249
Mottled to Barberpole:  4.38016896398
Probability of larger Mottled count: 0.0
Global Both:  52
--------------------------------
Inkawasi Solid:  4727
Inkawasi Mottled:  570
Inkawasi Barberpole:  208
Mottled to Barberpole:  2.74038461538
Probability of larger Mottled count: 4.78627441934146e-40
Inkawasi Both:  1
```

With color change signs, the four fundamental color types (light, mottled, barberpole, dark) could have been further refined to refer to up to an average of 16 total conceptually linked ideas (assuming the KDB average of 2 color types along the course of the cord—4!/(4-2)! + 4=16—including the four fundamental color types). Based on the frequency of these color change cord types (printed below), it seems that globally, solid/solid cords would have been the most unmarked and barberpole/barberpole or mottled/barberpole would have been the most marked (there are too few instances for this association to be completely clear), in line with what we saw for the markedness relations of the fundamental color sign types above.

```
In [10]: # Now, let's look at the Color Change cords for evidence of distinction:
         incahuasi_color_changes =
         incahuasi_color_combos_all[incahuasi_color_combos_all.Colors.str.contains('\r\n')]
         global_color_changes =
         global_color_combos_all[global_color_combos_all.Colors.str.contains('\r\n')]

         print "On average, the number of color types utilized on a color-change cord is:"
         # Calculate the number of times the color changes (+1 to include final entry):
         round(np.average([len([x for x in i if x in "r\n"]) + 1 for i in \
                 global_color_changes.Colors]))

         print
         print "Overall Global Color-Change Cords: ", len(global_color_changes)
         print "Global Solid: ",len(global_color_changes[global_color_changes.Color_Change \
                 == 'Solid'])
         print "Global Mottled and Solid: ", \
         len(global_color_changes[global_color_changes.Color_Change == 'Mottled_and_Solid'])
         print "Global Barberpole and Solid: ", \
         len(global_color_changes[global_color_changes.Color_Change=='Barberpole_and_Solid'])
         print "Global Multiple Mottled: ", \
         len(global_color_changes[global_color_changes.Color_Change == 'Multiple_Mottled'])
         print "Global Multiple Barberpole: ", \
         len(global_color_changes[global_color_changes.Color_Change == 'Multiple_Barberpole'])
         print "Global Mottled and Barberpole: ", \
                 len(global_color_changes[global_color_changes.Color_Change == \
                 'Mottled_and_Barberpole'])

         print "Probability of equal frequencies (chisquare): ", stats.chisquare([ \
                 len(global_color_changes[global_color_changes.Color_Change == 'Solid']), \
```

```
        len(global_color_changes[global_color_changes.Color_Change == \
        'Mottled_and_Solid']), \
        len(global_color_changes[global_color_changes.Color_Change == \
        'Barberpole_and_Solid']), \
        len(global_color_changes[global_color_changes.Color_Change == \
        'Multiple_Mottled']), \
        len(global_color_changes[global_color_changes.Color_Change == \
        'Multiple_Barberpole']), \
        len(global_color_changes[global_color_changes.Color_Change == \
        'Mottled_and_Barberpole']) \
        ])[0:2]

print "---------------------------------"
print "Overall Inkawasi Color-Change Cords: ", len(incahuasi_color_changes)
print "Inkawasi Solid:
",len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == 'Solid'])
print "Inkawasi Mottled and Solid: ", \
len(incahuasi_color_changes[incahuasi_color_changes.Color_Change ==
'Mottled_and_Solid'])
print "Inkawasi Barberpole and Solid: ", \
len(incahuasi_color_changes[incahuasi_color_changes.Color_Change ==
'Barberpole_and_Solid'])
print "Inkawasi Multiple Mottled: ",\
len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
'Multiple_Mottled'])
print "Inkawasi Mottled and Barberpole: ", \
len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
'Mottled_and_Barberpole'])
print "Inkawasi Multiple Barberpole: ", \
len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
'Multiple_Barberpole'])

print "Probability of equal frequencies (chisquare): ", stats.chisquare([ \
    len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == 'Solid']), \
    len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
        'Mottled_and_Solid']), \
    len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
        'Barberpole_and_Solid']), \
    len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
        'Multiple_Mottled']), \
```

```
        len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
            'Multiple_Barberpole']), \
        len(incahuasi_color_changes[incahuasi_color_changes.Color_Change == \
            'Mottled_and_Barberpole'])])[0:2]
```

```
On average, the number of color types utilized on a color-change cord is:

Overall Global Color-Change Cords:  2095
Global Solid:  1001
Global Mottled and Solid:  682
Global Barberpole and Solid:  187
Global Multiple Mottled:  160
Global Multiple Barberpole:  38
Global Mottled and Barberpole:  27
Probability of equal frequencies (chisquare):  (2286.4806682577564, 0.0)
---------------------------------
Overall Inkawasi Color-Change Cords:  143
Inkawasi Solid:  25
Inkawasi Mottled and Solid:  78
Inkawasi Barberpole and Solid:  18
Inkawasi Multiple Mottled:  13
Inkawasi Mottled and Barberpole:  5
Inkawasi Multiple Barberpole:  4
Probability of equal frequencies (chisquare):  (160.90209790209795,
6.357504103852104e-33)
```

Now we have an argument for how markedness would have worked for khipu cord colors through sophisticated color families composed of light colors (most unmarked), color combinations (intermediaries), and dark colors (most marked) (see in-text discussion in Chapter 4 for the full argument). Let's take the analysis one step further and see whether or not the color combinations found in the wrapped sticks at Inkawasi (see Chapter 4) match with color combinations in the Inkawasi color combination cords (and then more broadly in the KDB as a whole). I use color combination cords as my proxy for understanding khipu cord colors more generally because these cords are a part of larger color sign families (from solid light to color combination to solid dark) that encompass all other cord color types. By definition, color combination cords also include multiple colors, making it possible to match color pairings from the wrapped sticks (whereas solid color cords are necessarily missing their complementary opposite).

If so, then this would suggest that the wrapped sticks were used as codes for producing color signs within these sophisticated color sign families and that color sign families were conventionalized using semiotic technologies like the wrapped sticks at Inkawasi.

```
In [11]: # Drop color-change cords for now and I'll deal with them separately after I do this
         - part of the analysis:
         incahuasi_Brezine_color_counts = incahuasi_cords[~incahuasi_cords.Colors \
                 .str.contains('\r\n')].Brezine_Colors.value_counts()

         global_Brezine_color_counts = \
                 cords[~cords.Colors.str.contains('\r\n')].Brezine_Colors.value_counts()

         #Drop color counts for cords where no color was recorded:
         incahuasi_Brezine_color_counts = \
           incahuasi_Brezine_color_counts[incahuasi_Brezine_color_counts.index.values != '']
         global_Brezine_color_counts = \
             global_Brezine_color_counts[global_Brezine_color_counts.index.values != '']

         incahuasi_color_counts = pd.DataFrame([ \
             incahuasi_Brezine_color_counts.index.values, \
             incahuasi_Brezine_color_counts.values]).T
         global_color_counts = pd.DataFrame([ \
             global_Brezine_color_counts.index.values, global_Brezine_color_counts.values \
             ]).T

         # Observed Color Pairings in the wrapped sticks at Inkawasi:
         observed_Inkawasi = \
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B2,B3','B3,B2'])][1]) +\
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['M2,B2','B2,M2'])][1]) +\
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B3,B3'])][1]) +\
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['G2,B2','B2,G2'])][1]) +\
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B2,B2'])][1]) +\
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B2,A1','A1,B2'])][1]) +\
         sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B3,A1','A1,B3'])][1]) +\
```

```
sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B4,A1','A1,B4'])][1]) +\
sum(incahuasi_color_counts[incahuasi_color_counts[0].isin(['B4,B2','B2,B4'])][1])

observed_Global = \
sum(global_color_counts[global_color_counts[0].isin(['B2,B3','B3,B2'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['M2,B2','B2,M2'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['B3,B3'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['G2,B2','B2,G2'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['B2,B2'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['B2,A1','A1,B2'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['B3,A1','A1,B3'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['B4,A1','A1,B4'])][1]) +\
sum(global_color_counts[global_color_counts[0].isin(['B4,B2','B2,B4'])][1])


# Print out results
print "Number of observed Inkawasi color combo cords in common with Wrapped Sticks\
(not including cords with changing color): ", observed_Inkawasi
print "4 out of Top 5 unique Inkawasi cord color combos observed in wrapped sticks:"
print incahuasi_color_counts[incahuasi_color_counts[0].str.len() > 2][0].head(10)

print "Number of observed Global color combo cords in common with Inkawasi Wrapped\
Sticks: ", observed_Global
print "4 out of Top 5 unique global cord color combos observed in wrapped sticks:"
print global_color_counts[global_color_counts[0].str.len() > 2][0].head(10)
```

```
Number of observed Inkawasi color combo cords in common with Wrapped Sticks (not
including cords with changing color): 573
4 out of Top 5 unique Inkawasi cord color combos observed in wrapped sticks:
4     B3,A1
5     A1,B3
6     B3,B2
8     B2,B3
9     A1,B2
10    G3,B2
11    B4,A1
12    B4,B2
13    B2,A1
17    B2,B4
```

```
Name: 0, dtype: object
Number of observed Global color combo cords in common with
Inkawasi Wrapped Sticks:
8043
4 out of Top 5 unique global cord color combos observed in wrapped sticks:
4      B4,A1
5      B2,A1
6      B3,A1
7      B3,B2
11     B4,B3
12     B4,B2
13     A1,B3
15     G3,B2
16     G3,A1
18     B2,B3
Name: 0, dtype: object
```

It seems that the wrapped stick color combinations account well for color combinations of non-color change cords both at Inkawasi and Globally. Below, I wrote a function to see if there are similar matches across the color change cords as well (for any two colors entered into the function):

```
In [12]: def Match_Color_Pairing(entry1, entry2, cord_dataframe=incahuasi_cords):
             # Bring in Brezine Color Dictionary so I can look up matching color values
             BrezineColors = {'W': 'A1','PK': 'R2','RM': 'R3','SR': 'R3','VR': 'R4',
                              'SB':'N3','R0': 'N3','0R': 'N3','R': 'N4','YY': 'Y2',
                               'SY': 'Y3','0Y': 'Y3','PG': 'G2','GG': 'G3','DG': 'G4',
                              '0D':'G4','VG': 'G4','YG': 'G4','GR': 'G4','BL': 'H2',
                               'BG': 'H3','PB': 'H3','GL': 'H3','TG': 'H4','VB': 'H4',
                              'LC':'H4','YB': 'B2','BY': 'B2','AB': 'B2','RL': 'B2',
                               'GB': 'B2','FR': 'B3','0B': 'B3','MB': 'B3','LB': 'B3',
                              'BS':'B3','B': 'B3','RB': 'B3','NB': 'B3','EB': 'B3',
                               'CB': 'B4','BD': 'B4','HB': 'B4','BB': 'B4','KB': 'B4',
                              'RD':'B4','PR': 'B4','DB': 'B4','0G': 'L2','G': 'L3',
                               'G0': 'L3','0L': 'L4','D0': 'L4','LG': 'M2','RG': 'M3',
                              'MG':'M3','LA': 'M3','GY': 'M4','LD': 'M4','GA': 'M4',
```

```
                 'KG': 'M4','FB': 'Z5','0K': 'Z5','LK': 'Z5'
                }

# Clean Color Change Cord information so I can identify different types
color_change_list = [[j.replace('\t (0-0)','').strip() for j in i] for i in \
    cord_dataframe[cord_dataframe.Colors \
            .str.contains('\r\n')].Colors.str.split('\r\n')]
color_change_list = [filter(None,i) for i in color_change_list]
color_change_list = [[re.findall(r"[\w']+", j) for j in i] for i in \
            color_change_list]
color_change_list = [[[BrezineColors[k] for k in j if k in BrezineColors] \
             for j in i] for i in color_change_list]
flat_list = [item for sublist in color_change_list for item in sublist]
total_color_types_represented = len(flat_list)

total_pairings_anywhere = 0
total_pairings_at_one_level = 0
total_pairings_across_vertical_levels = 0
final_list = []
for cord in color_change_list:
#Calculate cord totals for # of pairings across vertical level and at one level
    tpavl_cord_sum = 0
    tpaol_cord_sum = 0

    #Calculate how many entries match across the length of the cord:
    entry1_match_count = 0
    entry2_match_count = 0
    combo_cord = 0
    for vertical_level in cord:
        if entry1 in vertical_level and entry2 in vertical_level:
            if entry1 != entry2:
                combo_cord +=1
                tpaol_cord_sum += 1
            elif len(vertical_level) > 1 and entry1 == \
            str(set(vertical_level)).replace("set(['", "").replace("'])", ""):
                combo_cord +=1
                tpaol_cord_sum += 1
        if entry1 in vertical_level and len(vertical_level) == 1:
            entry1_match_count += 1
        if entry2 in vertical_level and len(vertical_level) == 1:
```

```
                if entry1 != entry2:
                    entry2_match_count += 1
            #If cord has pair matches across vertical levels, assume a match:
            if (entry1_match_count and entry2_match_count) or (combo_cord and \
                entry1_match_count) or (combo_cord and entry2_match_count) \
                or (combo_cord>1):
                tpavl_cord_sum = 1
                total_pairings_across_vertical_levels += tpavl_cord_sum


            #If have matches from both of the above categories, assume cord is a match:
            if tpaol_cord_sum and tpavl_cord_sum:
                total_pairings_anywhere += 1
                final_list.append(str(cord))
            #Add sum of tpaol to overall running total
            total_pairings_at_one_level += tpaol_cord_sum

        return total_color_types_represented, total_pairings_anywhere, \
            total_pairings_at_one_level, total_pairings_across_vertical_levels, \
            final_list
```

```
In [13]: wrapped_stick_pairs = \
         [['B2','B3'],['M2','B2'],['B3','B3'],['G2','B2'],['B2','B2'],['B2'
                ,'A1'],['B3','A1'],['B4','A1'],['B4','B2']]

         incahuasi_matches = [Match_Color_Pairing(pair[0], pair[1], incahuasi_cords) \
                for pair in wrapped_stick_pairs]
         global_matches = [Match_Color_Pairing(pair[0], pair[1], cords) \
                for pair in wrapped_stick_pairs]

         print list(set(incahuasi_matches[0][4]).intersection(incahuasi_matches[1][4]))
         print "Inkawasi:"
         print "Overall Inkawasi Color-Change Cords: ", len(incahuasi_color_changes)
         print "Total Color Positions Represented: ", incahuasi_matches[0][0]
         print "Total Pairings (Full Cord): ", \
                sum([incahuasi_matches[i][1] for i in range(7)])
         print "Total Pairings at one level: ", \
                sum([incahuasi_matches[i][2] for i in range(7)])
         print "Total Pairings across vertical levels: ", \
                sum([incahuasi_matches[i][3] for i in
         range(7)])
```

```
    print "--------------------"
    print "Global"
    print "Overall Global Color-Change Cords: ", len(global_color_changes)
    print "Total Color Positions Represented: ", global_matches[0][0]
    print "Total Pairings (Full Cord): ", sum([global_matches[i][1] for i in range(7)])
    print "Total Pairings at one level: ", sum([global_matches[i][2] for i in range(7)])
    print "Total Pairings across vertical levels: ", sum([global_matches[i][3] for i in
    range(7)])
```

```
[]
Inkawasi:
Overall Inkawasi Color-Change Cords:  143
Total Color Positions Represented:  322
Total Pairings (Full Cord):  78
Total Pairings at one level:  111
Total Pairings across vertical levels:  92
--------------------
Global
Overall Global Color-Change Cords:  2095
Total Color Positions Represented:  4600
Total Pairings (Full Cord):  452
Total Pairings at one level:  606
Total Pairings across vertical levels:  785
```

Taking into account the identified matches found for color change cords, the number of cords accounted for at Inkawasi by the wrapped stick color combinations is thus most conservatively 573+78 = 651. This calculation only counts color change cords where all the color changes on the cord are consistent with the color combination being tested for (as opposed to counting any matches on the cord as a match with the wrapped stick), so it is a conservative measure of the number of matches with the wrapped sticks at the site.

```
In [14]: print 'Percentage of cord color combinations accounted for by wrapped stick \
    color pairs at Inkawasi: ',  \
    np.float(573+78)/np.sum(incahuasi_color_counts[incahuasi_color_counts[0] \
```

```
.str.len() >2][1])

print 'Percentage of cord color combinations accounted for by wrapped stick \
color pairs in KDB: ', \
np.float(8043+452)/np.sum(global_color_counts[global_color_counts[0].str.len() > \
2][1])
```

```
Percentage of cord color combinations accounted for by wrapped stick color pairs at
Inkawasi:  0.8367609254498715
Percentage of cord color combinations accounted for by wrapped stick color pairs in
KDB:  0.6740458620963262
```

I additionally performed a Monte Carlo simulation below to answer the question: How probable is it that we observe this number of matches between cord color combination and wrapped stick color pair by chance alone? I performed these simulations both for the Inkawasi khipus and those across the KDB. Interestingly, even though the color pairs on the wrapped sticks correspond to a smaller subset of color combination cords in the KDB as a whole than at Inkawasi, there is a statistically significant number of matches at both Inkawasi and globally across the KDB (the number of observed matches is well outside the bounds of the simulated counts for the database, or $p < 0.01$ that such an effect would occur by chance alone).

In order to perform this simulation, I first identified the number of color pairings on the wrapped sticks at Inkawasi. I only counted the first time a given sequence of two colors appeared on a specific wrapped stick, as the remaining color pairs on the stick are repetitions of these initial sequences. By this definition, there are 14 binary sequences of colors on the wrapped sticks found at Inkawasi:

Figure 4.2

1. MB, W
2. AB, YB
3. KB, W
4. MB, AB

5. YB, KB

6. W, MB

Figure 4.3

Left Stick:

7. YB, RL

8. PG, RL

9. YB, PG

Middle Stick:

10. LG, AB

Right Stick:

11. 0B, MB

Figure 4.5

Top Stick:

12. AB, W

Bottom Stick:

13. AB, W

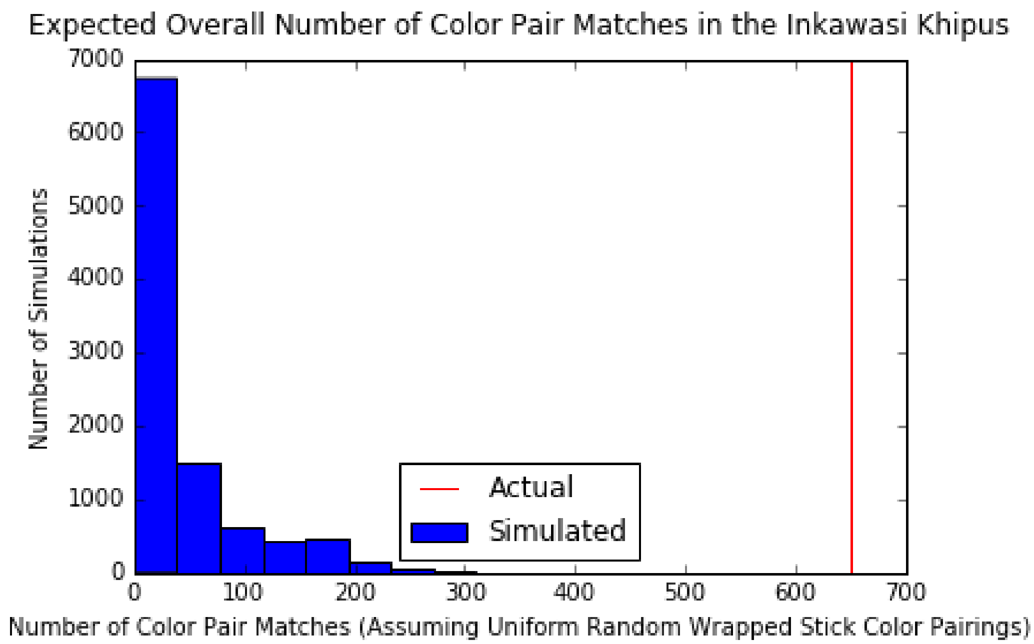
14. MB, AB

Then, I simulated 14 random pairs of colors (i.e. a simulated set of wrapped sticks) and calculated how many color combined cords (in the Inkawasi archive, as well as the KDB as a whole) the simulated wrapped sticks take into account. Repeating this same simulation 10,000 more times makes it possible to assess the probability of observing the number of cord color combination matches that I empirically observed between the real wrapped sticks and the Inkawasi and KDB khipus by comparing my empirical results with the simulated distribution.

```
In [15]: # For 14 unique color pairings on the wrapped sticks and 24 total color categories
         # recorded in the KDB:

         def Simulate_Color_Pairings(num_trials, num_pairings, color_counts_df):
             #Color Categories to simulate are from Carrie Brezine's simplified color scheme:
             color_categories = ['A1', 'R2', 'R3', 'R4', 'N3', 'N4', 'Y2', 'Y3', 'G2', 'G3',
```

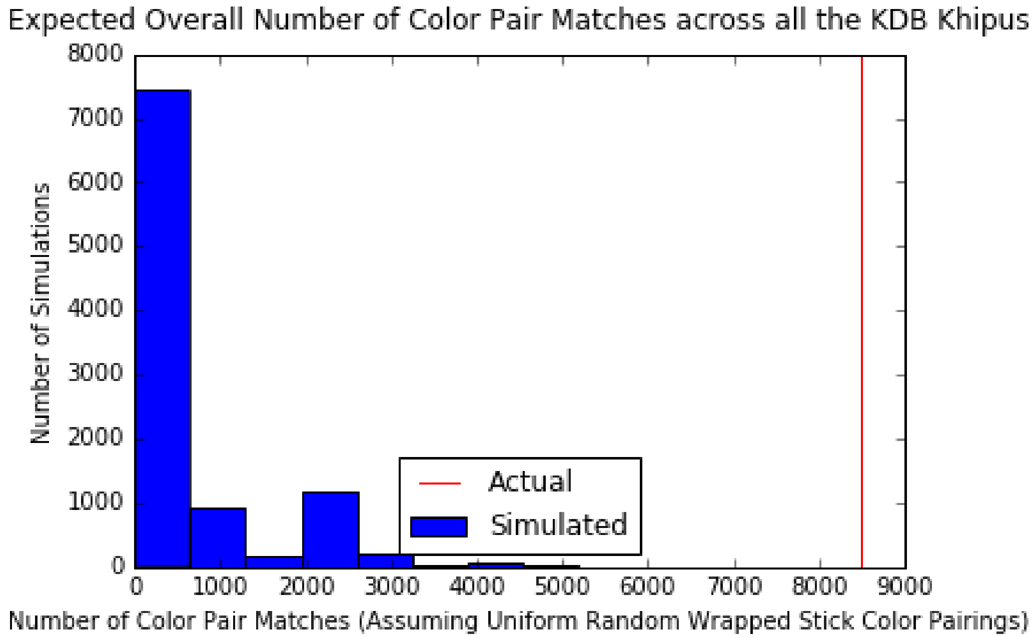
```
                         'G4', 'H2', 'H3', 'H4', 'B2', 'B3', 'B4', 'L2', 'L3', 'L4',
                         'M2', 'M3', 'M4', 'Z5']
    draws_total_color_combos = []
    for i in range(0, num_trials):
        pairings = []
        for j in range(0, num_pairings):
            #Add both the color combination and its reverse to the list, so we can
            #search for both:
            pairing_string = ','.join([color_categories[np.random.randint(0,23)], \
            color_categories[np.random.randint(0,23)]])
            pairings.append(pairing_string)
            pairings.append(','.join([pairing_string[-2:], pairing_string[:2]]))
        # Calculate how many color combo cords the simulated stick accounts for:
        draws_total_color_combos.append(sum(color_counts_df[color_counts_df[0] \
                .isin(pairings)][1]))
    # Return the distribution of total number of color combined cords the simulated
    # wrapped sticks take into account
    return draws_total_color_combos

# Random seed for reproducibility:
np.random.seed(0)

# Simulate 10,000 runs:
incahuasi_simulated_counts = Simulate_Color_Pairings(10000, 14, \
        incahuasi_color_counts)
global_simulated_counts = Simulate_Color_Pairings(10000, 14, global_color_counts)
```

In [16]:
```
# For observed color combination matches across the Inkawasi Khipu Archive
plt.hist(incahuasi_simulated_counts, label='Simulated')
plt.title("Expected Overall Number of Color Pair Matches in the Inkawasi Khipus", \
y=1.025)
plt.xlabel("Number of Color Pair Matches (Assuming Uniform Random Wrapped Stick \
Color Pairings)")
plt.ylabel("Number of Simulations")
plt.axvline(x=573+78, color = 'r', label='Actual')
plt.legend(loc='best')
plt.rcParams['figure.facecolor'] = 'white'
plt.show()
print 'Prob. of observing greater number of color pair matches than observed: ', \
    np.float(len([i for i in incahuasi_simulated_counts if i >= \
    573+78]))/len(incahuasi_simulated_counts)
```




```
Prob. of observing greater number of color pair matches than observed:  0.0
```

```
In [17]: # For observed color combination matches across the KDB
         plt.hist(global_simulated_counts, label='Simulated')
         plt.title("Expected Overall Number of Color Pair Matches across all the KDB  \
         Khipus", y=1.025)
         plt.xlabel("Number of Color Pair Matches (Assuming Uniform Random Wrapped Stick \
         Color Pairings)")
         plt.ylabel("Number of Simulations")
         plt.axvline(x=8043+452, color = 'r', label='Actual')
         plt.legend(loc='best')
         plt.rcParams['figure.facecolor'] = 'white'
         plt.show()
         print 'Probability of observing greater number of color pair matches than \
             observed: ',np.float(len([i for i in global_simulated_counts if i >= \
             8043+452]))/len(global_simulated_counts)
```




```
Probability of observing greater number of color pair matches than observed:  0.0
```

A.3 Chapter 5 Supplementary Code

First, I loaded all the packages I needed to perform my analysis:

```
In [1]: %matplotlib inline
        import numpy as np # Version 1.14.5
        import pandas as pd # Version 0.22.0
        import statsmodels.api as sm # Version 0.9.0
        import seaborn as sns # Version 0.9.0
        import matplotlib.pyplot as plt # Version 1.5.1
        from geopy.distance import vincenty # Version 1.11.0
        from sklearn import decomposition # Version 0.19.1
        from sklearn.preprocessing import StandardScaler
        from khipu_functions import BrezineColorConverter, isColorBanded, isColorSeriated
```

Then, I read in pre-wrangled KDB khipu data from CSV (available as supplemental online material for the dissertation on DASH, Harvard's open-access online repository: https://dash.harvard.edu/) to pandas dataframes.

```
In [2]: summaries = pd.read_csv('Data/Geo_Khipu_Data_8_1_2018.csv')
        cords = pd.read_csv('Data/Master_Cord_Data_8_1_2018.csv')

        # Set Cord and Khipu ID's as hierarchically related indices to facilitate
        # easy grouping for analysis:
        cords = cords.set_index(['Khipu', 'Cord']).drop("Unnamed: 0", 1)
```

For the purposes of assessing color banding and seriation, I was only interested in pendant cord patterns, so I dropped secondary cord recordings below, as well as top cords, mends, and knots in the primary cord. I only assessed pendant cord color patterns for each khipu.

Then, in order to assess recorded colors across investigators, I grouped closely related colors together under a grouping scheme developed by Carrie Brezine to account for folk color similarities and interobserver bias (`BrezineColorConverter()`), which I imported into the code at the outset from the `khipu_functions.py` file (available on DASH as supplemental online material as well as in Appendix A.4). A visual representation of the color scheme is available in Figure 4.8, in Chapter 4 of the dissertation.

```
In [3]: cords = BrezineColorConverter(cords)
        # cords dataframe with no secondary cords; just pendant and top:
        cords_noSecondary = cords.ix[cords.index.get_level_values("Cord") \
                .str.startswith('#1'),:]
        # cords dataframe with no secondary cords, top cords,mends,knots; only pendant cords:
        cords = cords_noSecondary.ix[~cords_noSecondary.index.get_level_values("Cord") \
                .str.contains('T|K|M')]
```

Then, I wrote a function that identifies whether a khipu is seriated, banded, both or neither. Pavlo Kononenko, the Database Administrator for the KDB, wrote a series a functions that performed these operations in R in 2012. I adapted the algorithms into Python and provided descriptions of the operations the functions perform (available in the `khipu_functions.py` file in Appendix A.4 and in the DASH supplemental online material). Below, I used these functions to identify banded and seriated khipus under the definition thresholds (Banded = 50% of the khipu is banded, Seriated = 4 instances of seriated cords) with the optimal statistical power (see in-text discussion in Chapter 5 for more information on these thresholds).

I then printed out how many banded and seriated khipus there are respectively and fit a logistic regression model to model the probability that a given khipu is seriated vs. banded based on its magnitude (see discussion of choosing a metric for magnitude in Chapter 5 for more information on this metric).

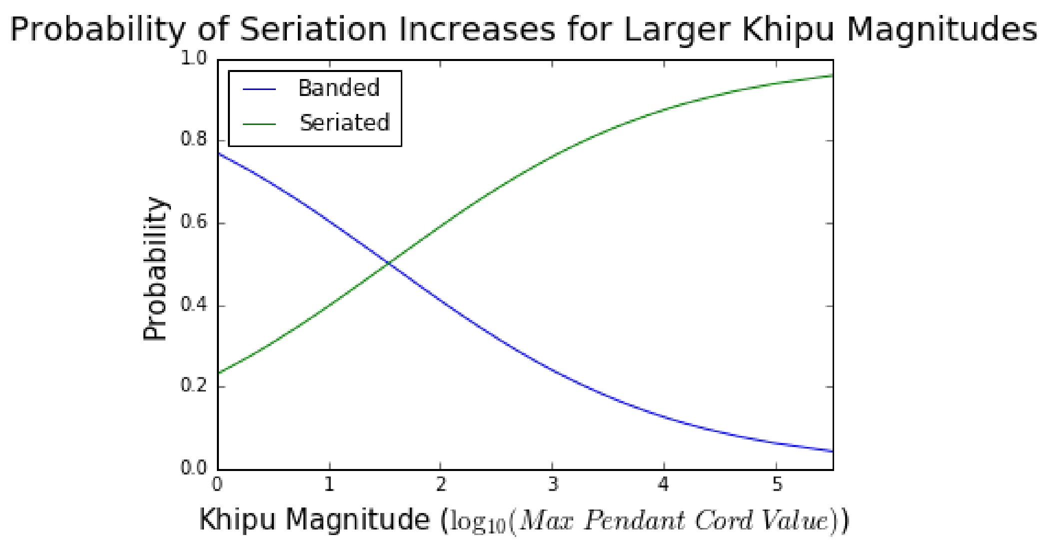
```
In [4]: #group cords together by khipu in preparation for assessing banding and seriation:
        gb_khipu = cords.groupby(level='Khipu')
        maxPendantValue = gb_khipu.Value.max()

        #determine whether each khipu is banded and/or seriated:
        banded = gb_khipu.Brezine_Colors.apply(isColorBanded, minPercBanded=.5)
        seriated = gb_khipu.Brezine_Colors.apply(isColorSeriated, requiredMatches=4)

        #separate khipus that are solely banded, solely seriated:
        bandedValues = maxPendantValue[banded][~seriated]
        seriatedValues = maxPendantValue[seriated][~banded]

        #Take the log (base 10) of each Max Pendant Value, so we can interpret each odds
        #increase as a 10-fold, decimal increase:
        logBandedValues = np.log10(bandedValues[bandedValues != 0])
        logSeriatedValues = np.log10(seriatedValues[seriatedValues != 0])

        #bring X variable into format compatible with statsmodels, adding in a constant term:
        value = pd.concat([logBandedValues, logSeriatedValues])
        value_mat = sm.add_constant(value.values, prepend = True)

        #set response variable, Y, so that banded values are the baseline comparison for
        #seriated khipus:
        pattern = pd.Series(np.concatenate([np.repeat(0, len(logBandedValues)),
                                            np.repeat(1, len(logSeriatedValues))
                                           ]), index=value.index)

        glm_binom = sm.GLM(pattern.values, value_mat, family=sm.families.Binomial())
        fit = glm_binom.fit()

In [5]: print "There are", len(bandedValues), "banded khipus and", len(seriatedValues), \
```

```
        "Seriated khipus"

There are 101 banded khipus and 168 Seriated khipus
```

```
In [6]: print fit.summary()

        probabilities = pd.DataFrame(fit.predict(), index=value.index)
        df = pd.DataFrame({'Pattern':pattern,
                      'Magnitude':value,
                      'Banded':1-probabilities[0],
                      'Seriated':probabilities[0]
                     })
        plt.figure(figsize=(20,10))
        df.groupby(df.Magnitude).agg({'Banded':np.mean, 'Seriated':np.mean}).plot()
        plt.title('Probability of Seriation Increases for Larger Khipu Magnitudes', size=18,
        y=1.02)
        plt.xlabel(r'Khipu Magnitude ($\log _{10}(Max \ Pendant \ Cord \ Value)$)', \
        fontsize=15)
        plt.ylabel('Probability', fontsize=15)
```

```
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                      y   No. Observations:                  262
Model:                            GLM   Df Residuals:                      260
Model Family:                Binomial   Df Model:                            1
Link Function:                  logit   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -160.18
Date:                Wed, 15 Aug 2018   Deviance:                       320.36
Time:                        11:54:01   Pearson chi2:                     262.
No. Iterations:                     4   Covariance Type:             nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -1.2090      0.369     -3.280      0.001      -1.932      -0.486
x1             0.7863      0.164      4.792      0.000       0.465       1.108
==============================================================================
```

```
Out[6]: <matplotlib.text.Text at 0xd937da0>

<matplotlib.figure.Figure at 0xe161828>
```



Thus, for each 10-fold max pendant cord value increase, the log odds of seriation increase by .786.

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = -1.209^{*} + 0.786^{*} \times (Khipu\ Magnitude)$$

*Statistically Significant ($p < 0.01$)

Then, I assessed whether there were any strong spatial relationships that modify this relationship of magnitude with color pattern. For this part of the analysis, I made use of the longitude and latitude data included for each khipu in `summaries` dataframe that I read in from a pre-wrangled CSV from the KDB. To arrive at longitude and latitude values, I only considered khipus with recorded provenances. Then, using the `geopy` (1.11.0) package, I fed the provenances into Open Street Maps' Nominatum search engine in order to assign each unique location longitude and latitude values.

Based on the latitude and longitude values, I then calculated another spatial variable 'DistFromCuzco' (in km) to identify possible relationships with the center of Tawantinsuyu:

```
In [7]: # Calculate the distance between each khipu provenance and Cuzco:

        coords_Cuzco = (summaries.Latitude[summaries.Provenance_CLEAN == 'Cuzco'].values,
                        summaries.Longitude[summaries.Provenance_CLEAN == 'Cuzco'].values)
        summaries['DistFromCuzco'] = summaries.apply(lambda x: vincenty((x.Latitude, \
                x.Longitude), coords_Cuzco).km, axis=1)
```

With spatial data formatted in the dataframe, I fit models with these spatial variables included in order to see if these spatial models do as well as the models that only include magnitude. In order to effectively model the relationship between color pattern and Longitude/Latitude coordinates, I reduced the longitude and latitude entries for each khipu to a single variable: the first principal component of the coordinates (that which accounts for the greatest possible variance in the Longitude/Latitude point cloud). I called this single variable "provenance" in the analysis below, since it is a general measure of spatial provenance, incorporating information from both Longitude and Latitude measurements.

```
In [8]: # Identify banded and seriated khipus + magnitude/lon/lat/dist for khipus with
          spatial data and drop storehouse accounting khipus from Incahuasi
         # (see in-text discussion in Chapter 5)
         summaries = summaries[summaries.Provenance_CLEAN != 'Incahuasi'].set_index('Khipu')

         bandedValues_sp = \
                 maxPendantValue[banded][~seriated][~maxPendantValue[banded][~seriated] \
                 .index.isin(set(maxPendantValue[banded][~seriated].index) \
                 - set(summaries.index))]
         seriatedValues_sp = \
                 maxPendantValue[seriated][~banded][~maxPendantValue[seriated][~banded] \
                 .index.isin(set(maxPendantValue[seriated][~banded].index) \
                 - set(summaries.index))]
         latBanded = summaries.Latitude[summaries.index.isin(bandedValues_sp.index)]
         lonBanded = summaries.Longitude[summaries.index.isin(bandedValues_sp.index)]
         distFromCuzcoBanded = \
                 summaries.DistFromCuzco[summaries.index.isin(bandedValues_sp.index)]

         latSeriated = summaries.Latitude[summaries.index.isin(seriatedValues_sp.index)]
```

```
lonSeriated = summaries.Longitude[summaries.index.isin(seriatedValues_sp.index)]
distFromCuzcoSeriated = \
        summaries.DistFromCuzco[summaries.index.isin(seriatedValues_sp.index)]

# Take the log (base 10) of each Max Pendant Value, so we can interpret odds
# increase as a 10 fold, decimal increase
logBandedValues_sp = np.log10(bandedValues_sp[bandedValues_sp != 0])
logSeriatedValues_sp = np.log10(seriatedValues_sp[seriatedValues_sp != 0])

# Bring X variables into format compatible with statsmodels, adding in a constant:
value_sp = pd.concat([logBandedValues_sp, logSeriatedValues_sp])
lat = pd.concat([latBanded, latSeriated])
lon = pd.concat([lonBanded, lonSeriated])
distFromCuzco = pd.concat([distFromCuzcoBanded, distFromCuzcoSeriated])

# Reduce dimensions of Lat/Lon from 2 (Lat, Lon) to 1 (provenance) via PCA
pca = decomposition.PCA(n_components=1)
x_std = StandardScaler().fit_transform(pd.DataFrame({'Longitude': lon,
                                                    'Latitude':lat}))
provenance=pca.fit_transform(x_std)
provenance=[i[0] for i in provenance]
X = pd.DataFrame({'Magnitude': value_sp, 'Provenance': provenance,
                'DistFromCuzco': distFromCuzco})
X_mat = sm.add_constant(X, prepend = True)
Y = pd.Series(np.concatenate([np.repeat(0, len(logBandedValues_sp)),
                              np.repeat(1, len(logSeriatedValues_sp))
                             ]), index=value_sp.index)

glm_binom_Cuzco = sm.GLM(Y.values, X_mat[['const', 'Magnitude', 'DistFromCuzco']], \
                family=sm.families.Binomial())
glm_binom_provenance = sm.GLM(Y.values,X_mat[['const','Magnitude','Provenance']],\
                family=sm.families.Binomial())

# Fit all the models:
model_fit_Cuzco = glm_binom_Cuzco.fit()
model_fit_provenance = glm_binom_provenance.fit()
```

With the models fit, we can look at the results:

With Distance From Cuzco:

```
In [9]: print model_fit_Cuzco.summary()

                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                      y   No. Observations:                  136
Model:                            GLM   Df Residuals:                      133
Model Family:                Binomial   Df Model:                            2
Link Function:                  logit   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -86.689
Date:                Wed, 20 Mar 2019   Deviance:                       173.38
Time:                        18:22:19   Pearson chi2:                     135.
No. Iterations:                     4   Covariance Type:             nonrobust
================================================================================
                   coef    std err          z      P>|z|      [0.025      0.975]
--------------------------------------------------------------------------------
const           -1.7857      0.890     -2.006      0.045      -3.531      -0.041
Magnitude        0.5958      0.220      2.708      0.007       0.165       1.027
DistFromCuzco    0.0015      0.001      1.250      0.211      -0.001       0.004
================================================================================
```

With Provenance (First Principal Component of Latitude and Longitude):

```
In [10]: print model_fit_provenance.summary()

                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                      y   No. Observations:                  136
Model:                            GLM   Df Residuals:                      133
Model Family:                Binomial   Df Model:                            2
Link Function:                  logit   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -81.892
Date:                Wed, 20 Mar 2019   Deviance:                       163.78
Time:                        18:20:57   Pearson chi2:                     134.
No. Iterations:                     4   Covariance Type:             nonrobust
```

```
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.9269      0.546     -1.698      0.089      -1.997       0.143
Magnitude      0.5909      0.228      2.586      0.010       0.143       1.039
Provenance    -0.5051      0.174     -2.900      0.004      -0.847      -0.164
==============================================================================
```

Distance from Cuzco is not statistically significant. However, Longitude and Latitude seem to both be playing a role in the overall pattern; you can see that their first principal component is statistically significant in the logistic regression model above. Looking over the data, I noticed that, in particular, the khipus from Northern Chile (South of -16 degrees Latitude) had an exaggerated influence on the model, so I removed those khipus and re-ran the same analysis below and found that spatial factors weren't a statistically significant influence across the rest of the Inka empire:

```
In [11]: # Identify banded and seriated khipus + magnitude/lon/lat/dist not from Chile
         summaries = summaries[summaries.Latitude > -16]
         bandedValues_sp = \
                 maxPendantValue[banded][~seriated][~maxPendantValue[banded][~seriated] \
                 .index.isin(set(maxPendantValue[banded][~seriated].index) \
                 - set(summaries.index))]
         seriatedValues_sp = \
                 maxPendantValue[seriated][~banded][~maxPendantValue[seriated][~banded] \
                 .index.isin(set(maxPendantValue[seriated][~banded].index) \
                 - set(summaries.index))]
         latBanded = summaries.Latitude[summaries.index.isin(bandedValues_sp.index)]
         lonBanded = summaries.Longitude[summaries.index.isin(bandedValues_sp.index)]
         distFromCuzcoBanded = \
                 summaries.DistFromCuzco[summaries.index.isin(bandedValues_sp.index)]

         latSeriated = summaries.Latitude[summaries.index.isin(seriatedValues_sp.index)]
         lonSeriated = summaries.Longitude[summaries.index.isin(seriatedValues_sp.index)]
         distFromCuzcoSeriated = \
                 summaries.DistFromCuzco[summaries.index.isin(seriatedValues_sp.index)]
```

```python
# Take the log (base 10) of each Max Pendant Value, so we can interpret odds
# increase as a 10 fold, decimal increase
logBandedValues_sp = np.log10(bandedValues_sp[bandedValues_sp != 0])
logSeriatedValues_sp = np.log10(seriatedValues_sp[seriatedValues_sp != 0])

# Bring X variables into format compatible with statsmodels, adding in a constant:
value_sp = pd.concat([logBandedValues_sp, logSeriatedValues_sp])
lat = pd.concat([latBanded, latSeriated])
lon = pd.concat([lonBanded, lonSeriated])
distFromCuzco = pd.concat([distFromCuzcoBanded, distFromCuzcoSeriated])

# Reduce dimensions of Lat/Lon from 2 (Lat, Lon) to 1 (provenance) via PCA
pca = decomposition.PCA(n_components=1)
x_std = StandardScaler().fit_transform(pd.DataFrame({'Longitude': lon,
                                                     'Latitude':lat}))
provenance=pca.fit_transform(x_std)
provenance=[i[0] for i in provenance]
X = pd.DataFrame({'Magnitude': value_sp, 'Provenance': provenance,
                'DistFromCuzco': distFromCuzco})
X_mat = sm.add_constant(X, prepend = True)
Y = pd.Series(np.concatenate([np.repeat(0, len(logBandedValues_sp)),
                              np.repeat(1, len(logSeriatedValues_sp))
                             ]), index=value_sp.index)

glm_binom_Cuzco = sm.GLM(Y.values, X_mat[['const', 'Magnitude', 'DistFromCuzco']], \
                family=sm.families.Binomial())
glm_binom_provenance = sm.GLM(Y.values,X_mat[['const','Magnitude','Provenance']],\
                family=sm.families.Binomial())

# Fit all the models:
model_fit_Cuzco = glm_binom_Cuzco.fit()
model_fit_provenance = glm_binom_provenance.fit()
```

```
In [12]: print model_fit_Cuzco.summary()
```

```
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                      y   No. Observations:                  130
Model:                            GLM   Df Residuals:                      127
Model Family:                Binomial   Df Model:                            2
```

```
Link Function:                  logit   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -80.923
Date:                Wed, 20 Mar 2019   Deviance:                       161.85
Time:                        18:24:11   Pearson chi2:                     129.
No. Iterations:                     4   Covariance Type:             nonrobust
================================================================================
                   coef    std err          z      P>|z|      [0.025      0.975]
--------------------------------------------------------------------------------
const           -1.9841      0.946     -2.096      0.036      -3.839      -0.129
Magnitude        0.5747      0.230      2.503      0.012       0.125       1.025
DistFromCuzco    0.0022      0.001      1.646      0.100      -0.000       0.005
================================================================================
```

```
In [13]: print model_fit_provenance.summary()
```

```
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                      y   No. Observations:                  130
Model:                            GLM   Df Residuals:                      127
Model Family:                Binomial   Df Model:                            2
Link Function:                  logit   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -81.030
Date:                Wed, 20 Mar 2019   Deviance:                       162.06
Time:                        18:24:21   Pearson chi2:                     129.
No. Iterations:                     4   Covariance Type:             nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -0.7592      0.544     -1.397      0.162      -1.825       0.306
Magnitude      0.5700      0.229      2.491      0.013       0.122       1.018
Provenance     0.2317      0.142      1.627      0.104      -0.047       0.511
==============================================================================
```

Thus, for khipus north of 16 degrees South, we see a strong magnitude effect, with no statistically significant spatial effect:

With Provenance (First Principal Component of Latitude and Longitude):

(n=130; Banded=48, Seriated=82)

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = -0.759 + 0.570^{*} \times (Khipu\ Magnitude) + 0.232 \times (Provenance)$$

With Distance from Cuzco:

(n=130; Banded=48, Seriated=82)

$$ln\left(\frac{P(Seriated)}{P(Banded)}\right) = -1.984 + 0.575^{*} \times (Khipu\ Magnitude) + .002 \times (Distance\ From\ Cuzco)$$

*Statistically Significant ($p < 0.05$)

A.4 Additional Python Functions (khipu_functions.py)

```
In [1]: def BrezineColorConverter(DataFrame):
            '''
            Description:
                Takes in the cords dataframe and translates 'Colors' column from folk
                categories to more generalized Brezine
                scheme.  Returns a dataframe including 'Brezine_Colors' as a column.
            Input:
                DataFrame : Pandas Dataframe containing cord data with a column named
                'Colors'
            Output:
                DataFrame : Pandas Dataframe containing the new column 'Brezine Colors'
            '''
            import numpy
            # Make dictionary associating Brezine and Folk categories, so that Brezine
            # values can be looked up using Folk keys:
            BrezineColors = {'W': 'A1',
                             'PK': 'R2',
                             'RM': 'R3',
                             'SR': 'R3',
                             'VR': 'R4',
                             'SB': 'N3',
```

```
'R0': 'N3',
'0R': 'N3',
'R': 'N4',
'YY': 'Y2',
'SY': 'Y3',
'0Y': 'Y3',
'PG': 'G2',
'GG': 'G3',
'DG': 'G4',
'0D': 'G4',
'VG': 'G4',
'YG': 'G4',
'GR': 'G4',
'BL': 'H2',
'BG': 'H3',
'PB': 'H3',
'GL': 'H3',
'TG': 'H4',
'VB': 'H4',
'LC': 'H4',
'YB': 'B2',
'BY': 'B2',
'AB': 'B2',
'RL': 'B2',
'GB': 'B2',
'FR': 'B3',
'0B': 'B3',
'MB': 'B3',
'LB': 'B3',
'BS': 'B3',
'B': 'B3',
'RB': 'B3',
'NB': 'B3',
'EB': 'B3',
'CB': 'B4',
'BD': 'B4',
'HB': 'B4',
'BB': 'B4',
'KB': 'B4',
'RD': 'B4',
```

```
                     'PR': 'B4',
                     'DB': 'B4',
                     'OG': 'L2',
                     'G': 'L3',
                     'GO': 'L3',
                     'OL': 'L4',
                     'DO': 'L4',
                     'LG': 'M2',
                     'RG': 'M3',
                     'MG': 'M3',
                     'LA': 'M3',
                     'GY': 'M4',
                     'LD': 'M4',
                     'GA': 'M4',
                     'KG': 'M4',
                     'FB': 'Z5',
                     'OK': 'Z5',
                     'LK': 'Z5'
        }
    #Make a copy of the input DataFrame:
    DataFrame = DataFrame.copy(deep=True)
    #Split Old Colors apart, Apply Brezine color scheme to each one, then recombine:
    DataFrame['Brezine_Colors'] = DataFrame.Colors.str.split("[^a-zA-Z0]") \
                                .replace(numpy.nan,'NaN', regex=True) \
                                .apply(lambda x: [BrezineColors[color] \
                                for color in x if color in BrezineColors]) \
                                .apply(lambda x: ','.join(x))
    #Return DataFrame, now including the Brezine equivalent colors
    return DataFrame

# The Following are adapted from R from Pavlo Kononenko's ColorFunctions.r:
def elIntersect(listOne, listTwo):
    intersecting = []
    for i in range(len(listOne)):
        if (len(listTwo) == len(listOne)) and (listTwo[i] == listOne[i]):
            intersecting.append(listTwo[i])
    return intersecting

def findColorPattern(pattern, searchData, rejectLevel):
    import pandas as pd
```

```
    import numpy as np

    x = list(pattern)
    y = list(searchData)

    inx = 0
    lx = len(x)
    resVector = [0]

    #For each khipu segment, determine how much of a pattern match there is:
    while inx < len(y)+1+lx:
        #compute ratio of matches to total pattern complexity (1 is a perfect match)
        matchCoeff = len(elIntersect(x,y[inx:(inx+lx)]))/lx
        inx += 1
        resVector.append(matchCoeff)

    #find local maxima for which matchCoeff is more than rejectLevel:
    rz = pd.Series(resVector)
    rxz = pd.rolling_apply(rz, 3, lambda x: x.argmax() == 1 and x[1] > rejectLevel, \
                center=True)
    #here, I modify Pavlo's original algorithm, to count the number of matches as
    #opposed to returning full cord data
    #this minimizes computation time for an operation not essential for my purposes.
    return np.sum(rxz)

def findPatternOnAKhipu(stepSize, khipu, rejectLevel=0.9, requiredMatches=2):
    #set matches to False until we find a color combo that repeats enough to be
    #considered a ``pattern''
    matches = False
    checked = []
    numCords = len(khipu)

    if numCords > stepSize:
        #for each unchecked color combination, run through the khipu and find matches
        #using 'findColorPattern' function
        for j in xrange((numCords - stepSize)):
            colors = khipu[j:j+stepSize]
            colConcat = '|'.join(colors)
            if colConcat in checked:
                continue
```

```
            else:
                #determine # of matches for a given cord combination; if there are
                #enough, it is a matched pattern.
                num_matches = findColorPattern(colors, khipu, rejectLevel)
                checked.append(colConcat)
                if num_matches > requiredMatches:
                    matches=True
    return matches

def isColorSeriated(khipu, requiredMatches=2):
    match = findPatternOnAKhipu(stepSize=2, khipu=khipu, rejectLevel=0.9, \
        requiredMatches=requiredMatches)
    isSeriated = (match == True)
    return isSeriated

def isColorBanded(khipu, minPercBanded=.2):
    import numpy as np
    groups = np.repeat(np.nan, 1000)
    inx = 0
    count = 0
    prevColor= "Dummy"
    numCords = len(khipu)

    for i in xrange(numCords):
        if khipu[i] == prevColor:
            count+=1
        else:
            prevColor = khipu[i]
            count = 1
            inx = inx + 1
        groups[inx] = count

    realLen = np.sum(~np.isnan(groups))
    groups = groups[0:realLen]
    grouped = groups[groups>2]

    #If more than 20% of cords are banded, it's a banded khipu:
    isBand = np.sum(grouped)/numCords > minPercBanded
    return isBand
```