UC San Diego

UC San Diego Electronic Theses and Dissertations

Title

Examining Wari influence in the Las Trancas Valley, Peru using oxygen isotopes from bone carbonate

Permalink

https://escholarship.org/uc/item/971719tg

Author

Henry, Erin-Marie Lelik

Publication Date

2008

Peer reviewed|Thesis/dissertation

eScholarship.org Powered by the California Digital Library
University of California

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Examining Wari Influence in the Las Trancas Valley, Peru using Oxygen Isotopes from Bone Carbonate

A Thesis submitted in partial satisfaction of the requirements for the degree
Master of Arts

in

Anthropology

by

Erin-Marie Lelik Henry

Committee in charge:

Professor Margaret Schoeninger, Chair
Professor Paul Goldstein
Professor Jim Moore

2008

Copyright
Erin-Marie Lelik Henry, 2008
All rights reserved

The Thesis of Erin Marie Lelik Henry is approved and it is acceptable in quality and form for publication on microfilm:

_____

_____

_____

Chair

University of California, San Diego

2008

TABLE OF CONTENTS

Signature Page……iii

Table of Contents……....iv

List of Figures ……..……...…….. v

List of Tables …….……... vi

List of Graphs …….……...…….. vii

Acknowledgements……..viii

Abstract…….……...…….. ix

Introduction……...…..…… 1

Background……...…..…… 7

Environment, Water Systems and the Puquio……....…… 7

Oxygen Isotope Ratios and Water Supply……...…..…….. 9

Expectations……..…… 14

Materials and Methods……..…….……16

Results…..……..……19

Discussion……..……20

Conclusion……..……...22

Appendix…….……...…….24

References……....…….....45

LIST OF FIGURES

Figure: 1 Map of Peru ……...……...…...24

Figure: 2 Location of Collota and Netahaha in the Cotahuasi Valley…….…….....…25

Figure: 3: Settlement patterns of the SNR during Wari occupation in Middle Horizon.....26

Figure 4: Location and characteristics of the Nasca, Taruga, Las Trancas and Tierras Blancas valleys……...…27

Figure 5: Cross section of a trench-type puquios and a gallery-type puquios...….....28

Figure 6: Schematic O-isotope fractionation of water in the atmosphere ……..…29

Figure 7: Diagram showing gradient between warmer temperatures and higher $\delta^{18}O$ values at lower elevations to cooler temperatures and lower $\delta^{18}O$ values at higher elevations……..….30

Figure 8: The increase in ^{18}O abundance in a quantity of vapor from which water has been separated by cooling from T_0 to T……...……..…31

Figure 9: $\delta^{18}O$ from precipitation and water sources worldwide……..……....……32

Figure 10: $\delta^{18}O$ from precipitation and water sources from Central and South America .....…...32

Figure 11: Fluxes of oxygen contributing to isotopic ratio of body water reservoir……..……..…….33

Figure 12: FTIR spectra showing location of absorption bands ……..……....34

LIST OF TABLES

Table 1: Chronology of the South Coast of Peru……..……...…….35

Table 1: $\delta^{18}O$ from precipitation and water sources of Central and South America……..……36

Table 3: Period, Catalogue Number, CI and Isotope Values for Bone Carbonate……..…….37

Table 4: Mean and Standard Deviation for each time period……..…....40

Table 5 Multiple Comparisons Using Tukey HSD ……..……...…..41

LIST OF GRAPHS

Graphs 1: Plot of $\delta_p{}^{18}O$ ($^o/_{oo}$ SMOW) of deer and fish bones against yearly average Temperature……...……42

Graphs 2: Linear distribution of Body Water $\delta_p{}^{18}O$ and Water Source $\delta^{18}O$ for fish, pig, human, and deer……..…43

Graph 3: Plot of $\delta^{18}O$ and $\delta^{13}C$ of Bone Carbonate from Nasca and Imperial Period……..……...44

ACKNOWLEDGEMENTS

This research was funded by a National Science Foundation Postdoctoral Fellowship #0409891 (CMK and MJS) and the Regents of the University of California (MJS), and was facilitated by the Instituto Nacional de Cultura del Peru and the Museo Nacional de Arqueologia, Antropoogia, e Historia del Peru (MNAAHP) in Lima, Peru from where the samples were taken. I thank Jyelynne Nguyen and Andrew Somerville for help in the preparation of samples for analysis and Dr. Bruce Deck for assistance in sample analysis at the Scripps Institution of Oceanography's Unified Analytical Facility (SIO-ULF). I would also like to thank Alyssa Crittenden for her assistance in running the statistical analysis.

ABTRACT OF THE THESIS

Examining Wari Influence in the Las Trancas Valley, Peru using Oxygen Isotopes from Bone Carbonate

by

Erin-Marie Lelik Henry

Master of Arts in Anthropology

University of California, San Diego, 2008

Professor Margaret Schoeninger, Chair

The Nasca region of the Las Trancas Valley in south coastal Peru is considered to be one of several peripheral regions which were influenced by the highland Wari empire during the Middle Horizon (750-1000 AD). They are thought to have had socioeconomic and political ties with the neighboring empire. The Wari are considered to be one of the first expansive states that developed in the Andean region (Schreiber, 1992; 1999). The extent of Wari control based on archaeological evidence and diet reconstruction,

however, remains inconclusive. I tested the hypotheses regarding the nature of Wari influence (i.e. presence of Wari emissaries) in the Las Trancas Valley by analyzing the oxygen isotope of human bone from burials dating prior to and during Wari influence. The oxygen isotope was used to determine whether or not individuals from high-altitude regions were present in low-altitude regions. Burials during Wari influence, distinguished by presence of either local Loro ceramics or imperial Chakipampa style ceramics, showed similar isotope patterning for individuals from higher elevation. The construction of the puqio during the Late Nasca most likely contributed to the differences seen in $\delta^{18}O$ of bone carbonate, but continued decrease during Late Nasca and Imperial period further support the idea that foreign born individuals were present.

INTRODUCTION

The Nasca culture of the arid south coastal region of Peru existed during the Early Intermediate Period (1-750 AD) (Table 1). Much of the archaeological analysis in this area has concentrated on the Southern Nasca Region (SNR) (Figure 1) which includes the Nasca, Taruga and Las Trancas valleys (Figure 4) (Schreiber and Lancho Rojas, 1995; 2003; Kellner and Schoeninger, 2007). The Nasca are known most notably for the Nasca lines, or geoglyphs, (Aveni, 1990), but they are also well known for their colorful and intricate designed textiles and ceramic art (Proulx, 1968; Vaughn, 2000). The range of variation found in Nasca ceramics and textiles found in the SNR is one example of the great diversity and complexity in sociopolitical life found throughout what is known as the Rio Grande de Nasca drainage system (Carmichael, 1995; Schreiber and Rojas, 2003; Silverman 1993; Vaughn, 2004). In Early Nasca (1-450 AD), most settlements were small villages scattered throughout the SNR river valley system with little economic or status differentiation (Schreiber, 1999; Schreiber and Lancho Rojas, 1995; Silverman, 1993, 2002; Vaughn, 2000). Control of the region belonged primarily to a small group of priests or shamans who organized ritual gatherings and feasts at ceremonial centers such as Cahuachi which was a large site situated close to a large source of freshwater (Valdez, 1994; Silverman, 1993; Silverman and Proulx, 2002). Iconography found on pottery and textiles is believed to be the primary source of communication used to spread religious ideology throughout the region.

With the development of a sophisticated hydraulic technology, settlements

expanded and shifted to newly arable lands within the SNR (Schreiber and Lancho Rojas, 1995, 2003). During the Middle Nasca (450-550 AD) and Late Nasca period (550-750 AD), settlements grew dramatically in size; however, construction at Cahuachi stopped (Schreiber, 1999; Schreiber and Lancho Rojas, 1995, 2003; Silverman, 1993, 2002). Irrigation technology allowed for continued use of crops such as maize and expanded diet to other crops such as beans, squash and peppers (Schreiber and Rojas, 2003; Silverman, 1993; Vaughn, 2004). Ceramic and textile iconography as well as the presence of more elaborate mortuary architecture indicate a continued conglomeration of power to the Nasca elite as well as an increase in sociopolitical complexity during this period (Silverman, 1993; 2002)

The highland Wari empire (Figure 1) came to power within the Nasca region during the Middle Horizon period (750-1000 AD). Influence of Wari ceramic style, iconography and technology as well as changes in burial patterns during the Early Intermediate (1-750 AD) suggest that a connection between these two regions existed before the first physical evidence of Wari occupation (Menzel, 1964; Silverman, 1993). The Huarpa style ceramic found in the Wari highlands exhibit certain aspects of the Nasca style (Menzel, 1964; Knobloch, 1976). Nasca iconography such as mythical animals and trophy heads are found on Wari style ceramics. Nasca use of color, slip painting and high-temperature firing are examples of ceramic technology adopted by the Wari (Menzel, 1964; Silverman, 1993). Nasca burial practices of burying individuals in seated or flexed positions also appear to be adopted by the Wari during the Early Intermediate period (Menzel, 1964; Rowe, 1995).

Ceramic styles begin to appear in offering deposits, habitation and burial sites which is believed to be some of the first evidence for Wari expansion into the region. The Pacheco site (Figure 3) in the lower valley was a major Wari offering deposit and mirrors the archaeological finds found at the Conchopata site (Figure 1) near the Wari capital in the highlands (Menzel, 1964). The presence of a large quantity of Wari ceramics (approximately 3 tons), local Middle Horizon pottery and habitation sites suggest that this location might have functioned as more than just a ritual location. According to Schreiber (2001), this site might have also functioned as an administrative center.

The Wari appear to have made great investment in peripheral regions by building administrative centers. Empires interact with peripheral regions with varying degrees of direct and indirect control, although there are two general types of imperial strategies for provincial control. Territorial or imperial states exercise direct control through implementation of imperial administrators who give direct allegiance to the imperial core (Doyle, 1986; Schreiber, 1992). Patrimonial empires or hegemonies, however, establish control through collaboration with local elites (Doyle, 1986). Archaeological evidence in these regions suggests the Wari Empire used imperial strategies to establish control. In regions such as in the Carhuarazo Valley, distinctive Wari architecture and artifact inventory establishes the presence of Wari administrative centers at Jincamocco (Figure 1), and three other smaller centers throughout the valley (Schreiber, 1992, 1999).

Direct control can also result in significant changes in subsistence strategies or presence of imperial architecture in peripheral regions (D'Altroy and Hastorf, 2001;

Larsen et al., 2001; Kellner and Schoeninger, 2007). In the Carhuarazo Valley, contact with the Wari led to a major shift in agriculture with a heavy reliance on maize agriculture (Schreiber, 1992, 1999). Direct Wari control in the Cotahuasi Valley is suggested through the presence of imperial architecture found at newly established sites in Collota and Netahaha (Figure 2) (Jennings and Craig, 2001). The presence of Wari ceramics, Wari architectural styles and shifts in settlement patterns suggests that Pikillacta (Figure 1) of the Cuzco region was a Wari administration center. (McEwan, 1996). Wari ceramics and architecture of Cerro Baul in the Moquegua Valley (Figure 1) provides evidence for direct control, however, the presence of Tiwanaku architecture in this region implies a joint control of the region (Williams, 2001; Moseley et al, 2005). Introduction of new sites with intrusive imperial architecture, as well as, significant changes in diet, ceramic/textile iconography, and settlement patterns are key attributes for an imperial power imposing direct control in a region (McEwan, 1996; Rowe, 1963; Schaedel, 1966; Schreiber, 1987; Smith and Montiel, 2001: 249).

A decline in the number of Nasca sites found in the northern Nasca and Taruga valleys occurred during the Middle Horizon (750-1000 AD) (Silverman, 2002). The Nasca appear to have moved away from the northern valleys to the most southern Las Trancas Valley. Wari imperial settlements such as Pacheco (Figure 3) are established while only small villages of local people remain in the Wari occupied northern valleys. The movement of local people away from imperial settlements suggests that the relationship between Wari and Nasca was becoming more confrontational (Schreiber, 1999; 2001). Settlement patterns also suggest a shift from smaller, more independent

villages to a more centralized system of town centers such as the one found at Huaca del Loro in the Las Trancas Valley.

Depopulation of more northern Nasca settlements near Wari sites occurred simultaneously with expansion of populations in southern valleys (Schreiber, 1999). In the Las Trancas Valley, the Wari Chakipampa style ceramics found in Nasca cemeteries and habitations are the only clear archaeological evidence for Wari contact (Menzel, 1964; Schreiber, 1992). The large settlement of Huaca del Loro is believed to be a major administration center for the area (Schreiber and Lancho Rojas, 2003). It is suggested the intermediate-elites of the area obtained their position of power through cooperation or possibly organized resistance to the Wari Empire (Conlee and Schreiber, 2006). Small habitation sites and burials with Wari ceramics are present. There is however, no archaeological evidence such as architecture or the presence of Wari infrastructure (i.e. road system) to suggest that the Wari directly controlled Huaca del Loro (Schreiber, 1992; Schreiber and Lancho Rojas, 2003).

Lack of provincial sites in the Las Trancas Valley that may indicate direct control could signify that Wari interaction in this area was different from more northern Wari controlled regions. (Schreiber, 1992, 1999) Artifacts, such as ceramics and textiles, found in Nasca cemeteries and habitation sites do not provide enough evidence to determine what type of interaction existed (Menzel, 1964). The Nasca diet does not appear to have changed significantly, yet the Nasca had access to a wide range of food, pre-imperial, which only increased slightly after contact with the Wari (Kellner and Schoeninger, 2007). Imperial strategies often result in extreme shifts in subsistence strategies within peripheral societies (D'Altroy and Hastorf, 2001; Larsen et al, 2001).

This suggests that the Wari had a different influence in the Las Trancas Valley compared with other neighboring valleys. Ceramic styles found at cemeteries and offering deposits indicate a Wari/ Nasca relationship, but lack of Wari settlements in the region indicates a degree of independence from the neighboring empire.

The analysis of oxygen isotopes in human bones is one tool that can be used as a means of identifying individuals who did not grow up in or come from the locations in which they are buried. In order to better understand the Wari/Nasca relationship in the Las Trancas Valley, I will use the ^{18}O:^{16}O isotope ratio in bone to assess the presence of Wari emissaries at Huaca del Loro. I will also assess the presence of local Nasca migrants from northern SNR valleys buried in Las Trancas Valley cemeteries.

BACKGROUND

Environment, Water Systems and the Puquio

The Nasca and Wari settlements of the lower valley occupy what is known as the Rio Grande de Nasca drainage system. This system consists of a series of river valleys which start in the Andes Sierra mountain range with its highest elevation of around 6000 meters. At lower elevations these river valleys converge into a single channel which empties into the Pacific Ocean. The river valleys are separated by a narrow range of hills. The distance in separation between river valleys increases when moving up in elevation into the more rugged highland terrain. The close proximity of river valleys in the lowlands is thought to have contributed to the settlement patterns and integrated social system found in this region (Menzel, 1964).

The Rio Grande de Nasca is routinely divided into the northern and southern tributary groups. The southern group includes the Aja, Tierras Blancas, Taruga, and Las Trancas tributaries (Figure 4) (Schreiber and Lancho Rojas, 2003). Each valley is subdivided by rainfall and elevation (Figure 4). Each river tributary is fed by seasonal precipitation in the Andes Mountains. The catchments of the southern Nasca tributaries are substantially smaller than those of the northern tributaries due in part to the extension of the Acari drainage to the east in the sierra (Schreiber and Lancho Rojas, 2003). The smaller catchments result in a low initial river volume in the southern valleys compared to the northern valleys. The southern valley, as seen in Figure 4, is divided into the Upper, Middle, and Lower Valley (Schreiber and Lancho Rojas, 2003). In the Upper Valley and parts of the Lower Valley, where river flow is perennial, farming or a form of river-based irrigation agriculture is possible. The Upper Valley and parts of the Lower

Valley, where river flow is perennial, farming or a form of river-based irrigation agriculture is possible. The transitional zone known as the "Zone of Infiltration" (Schreiber, 1992) can be farmed with river water irrigation, but during drought years farming this area would be difficult. River alluvium creates a moderate to high infiltration capacity or transmission loss in river water volume resulting in what are termed "influent streams" (Schreiber and Lancho Rojas, 2003). This means that these tributaries flow partially on the surface, and for some stretches drop completely below the surface. In areas which are devoid of surface water, technology to access these subterranean sources of water year round would be the only way for permanent habitation.

A well system (i.e. the puqio) would have allowed the Nasca to inhabit the Middle Valley by providing access to these subterranean sources of water. The puqio is a horizontal well that exists in either an open trench or a subterranean gallery that connects a point on the surface with subsurface water (Figure 5) (Schreiber and Lancho Rojas, 1992). The underground water is filtered through the puquio where it is emptied into either a small reservoir (kocha) or directly into irrigation canals. Puquios provide both a reliable source of irrigation water and a year-round supply of domestic water (Schreiber and Lancho Rojas, 1992). In the Las Trancas Valley, between the elevations of 525 and 675 meters above sea level, there are several puquios that today still function much as they did when they were first constructed in the Middle to Late Nasca.

Oxygen Isotope Ratios and Water Supply

Also known as the Dole effect, the ratio of $^{18}O/^{16}O$ in atmospheric water oxygen is greater than oxygen in ocean water (Lane and Dole, 1956; Gat, 1996; Hoefs, 2004). Water vapor leaving the surface cools as it rises and the rain formed when the dew point is reached preferentially removes the heavy isotope, ^{18}O, from the air. This results in rain leaving the system enriched in ^{18}O (Hoefs, 2004). Land water sources are replenished by meteoric water such as rain or air moisture and the $^{18}O/^{16}O$ ratio decreases in association with distance from the sea as moisture is condensed and deposited (Figure 6) (Bowen and Wilkenson, 2002). The ^{18}O:^{16}O in water vapor is increasingly reduced with each rainfall**.**

Precipitation and surface water also have increasingly lower $\delta^{18}O$ values with increasing altitude. This altitude effect (Dansgaard, 1964; Land et al., 1980; Koch et al., 1989; Quade et al., 1992; Koch et al., 1995) has been recognized in all the major mountain belts of the world. In regions with a single dominant moisture source, (i.e. the ocean) precipitation and surface waters at high elevations are often strongly depleted in ^{18}O relative to ^{16}O (Poage and Chamberlain, 2000; 2001). The relative abundance of $\delta^{18}O$ in atmospheric water vapor is due in part to the temperature of the evaporation, the origin of the vapor and the earlier precipitation of water due to cooling (Figure 7) (Dansgaard, 1964; Hoefs, 2004) which can vary at different elevations. Minerals formed on a rising surface and preserved in rock record will also initially record warmer temperatures and higher $\delta^{18}O$ values, progressing toward cooler temperatures and lower $\delta^{18}O$ values as elevation increases. (Champerlain and Poage, 2006). Isotopic distillation curves ($\Delta\delta^{18}O$ precipitation per °C cooling) are not quite linear over temperature

changes of 20°C, however, they are very close to linear. For example, air moisture with initial temperatures of 0° and 20°C will average a change in the isotopic composition of precipitation by 0.64 and 0.33 permil/°C, respectively, over 20°C of cooling (Figure 8) (Dansgaard, 1964). The $\delta^{18}O$ data from precipitation and surface waters throughout the globe (Figure 9, Figure 10 and Table 2) mirror this near linear empirical relationship between the change in $\delta^{18}O$ and change in elevation (Poage and Chamberlain, 2001).

In mammals, the oxygen isotopic composition of body water reflects the $\delta^{18}O$ of water sources consumed as well as the fluctuation of substances containing oxygen specific to that environment (Luz et al., 1984; Luz and Kolodny 1985). Oxygen enters the mammalian body through drinking water (Longinelli and Paladino, 1980; Longinelli, 1984; White and Spence, 1998; Kohn and Mclver, 2006), inhaled molecular oxygen, and water in food (Figure 11) (Luz et al., 1984; Luz and Kolodny, 1985; White and Spense, 1998; Straight et al, 2007). As part of the oxygen flux, water is lost as vapor, sweat, urine, and in feces. The relationship between the $\delta^{18}O$ values of local drinking water and body water is controlled by the balance between inputs and outputs. Because most mammals larger than about 1 kg have a constant body temperature near 37°C, their body water $\delta^{18}O_{bw}$ remains relatively constant. (Longinelli, 1984; Luz et al., 1984; Luz and Kolodny, 1985; Cossins and Bowler, 1987; D'Angela and Longinelli, 1990; Luz et al, 1990; Bryant and Froelich, 1996).

Species physiology can also have an effect on $\delta^{18}O$ values (Bryant and Froelich, 1995; Kohn 1996; Kohn et al., 1996). Mammals have what is termed endothermic physiology. Endothermy is a thermoregulatory strategy where a high and constant body temperature (within ± 2 °C) is maintained through metabolic heat production.

Ectotherms on the other hand have a body temperature that is linked to that of the environment and to behavioral thermoregulatory strategies. Because oxygen isotope fractionation between bone and body water is temperature-dependent endotherms are expected to have distinct $\delta^{18}O$ values compared to ectotherms (see Graph 1). Several researchers have shown that, even with these sources of fractionation that affect $\delta^{18}O$ values, a linear relationship remains between $\delta^{18}O$ of body water and $\delta^{18}O$ of water source (Graph 2) (Bryant and Froelich 1995; Kolodny et al, 1983; Levinson et al., 1987; Longinelli 1984; Luz et al., 1984). Intrapopulational variation in $\delta^{18}O$ values for endothermic species (deer, wild boar, pigs) and humans appear to be quite low generally (i.e., 1 $^{o}/_{oo}$) (Barrick et al, 1992; Budd et al. 2004; Longinelli 1984). Explanations for endothermic species with significant variation in $\delta^{18}O$ of body water include higher rates of mobility, having a more heterogeneous diet or variation in the dissipation of body heat (i.e. illness or excessive exercise) (Luz et al., 1990; Stuart-Williams and Schwarcz 1997).

Oxygen isotopes can also be measured in bone and teeth composition. Bone formation usually occurs during childhood or as a young adult (Luz et al., 1984). Because the process of bone mineralization involves the enzyme ATP (adenosine triphosphate) there is a fast exchange of oxygen between bone mineral and body water, forming a relatively long-term record of the $\delta^{18}O$ (Leonard & Scullin, 1969). The $^{18}O/^{16}O$ ratios should only be altered when significant remodeling of bone takes place due to different environmental circumstances or major changes in bodily stresses. Therefore, oxygen ratios should represent in humans an average of at least a few years. Children should take on new signatures much more quickly than adults, with any changes due

to remodeling decreasing as bone remodels more slowly with age (Longinelli 1984). As a result, preserved isotopic ratios of oxygen should represent long term averages, and seasonal fluctuations in the $\delta^{18}O$ of body water should not significantly affect these ratios (Ayliffe & Chivas, 1990; Stuart-Williams & Schwarcz, 1997).

Both the phosphate (PO_4) and carbonate (CO_3) components of tooth and bone can be measured for $\delta^{18}O$. Carbonate can be more susceptible to diagenetic alteration (Iacumin et al., 1996; Kohn and Cerling, 2002) particularly when dealing with bone, but because of its ease of analysis it is typically used (Barrick et al., 1992; Bryant et al, 1996) The methodology for analyzing phosphate on the other hand can be difficult (Tudge, 1960; Longinelli and Nuti, 1973; Karhu and Epstein, 1986). Both carbonate and phosphate, however, can provide accurate information on $\delta^{18}O$ of a bone sample.

A technique to determine the integrity of $\delta^{18}O$ in phosphate or carbonate bone is Fourier Transform Infrared Spectroscopy (FTIR). FTIR spectroscopy is performed by irradiating a sample with an infra-red beam. Radiation is absorbed at certain frequencies for different functional groups such as HPO_4^{2-}, PO_4^{3-} , and CO_3^{2-}. The intensity of this absorption is proportional to the concentration of the absorbing molecule (Sponheimer and Lee-Thorp, 1999). FTIR spectroscopy (Figure 12) provides information on the molecular species present, concentration of molecules and the overall pattern of absorbance (Shemesh, 1990). From this, the chemical composition, crystallographic structure and the diagenetic properties of bone after deposition in the archaeological record can be determined (Termine and Posner, 1966; Bonar et al., 1991; Rey et al., 1991). The Crystallinity Index (CI) increases with fossilization (Weiner and Bar-Yosef,

1990; Michel, Ildefonse and Morin, 1996; Stuart-Williams et al., 1996; Wright and Schwarcz, 1996) and can be measured by the degree of the PO_4^{3-} band splitting. CI is defined by equation:

$$CI = (A_{605} + A_{565}) / A_{595}$$

FTIR differentiates between pristine (unaltered) and altered species. It is suggested that only samples with low crystillinity indices (C.I. < 3.8) should be considered pristine or unaltered (Shemesh, 1990).

EXPECTATIONS

Stable isotope analyses of individuals buried at cemeteries in the Las Trancas Valley are used to investigate the Wari influence in the region. If the Wari were sending emissaries to Las Trancas Valley, it is expected that the water sources accessed by the Wari would have depleted $\delta^{18}O$ due to the altitude and distance of source water of the highlands from coastal regions. As a result, individuals who migrated to lower valley regions would be expected to have bone carbonate with lower $\delta^{18}O$ values compared with Nasca inhabitants. Changes in $\delta^{18}O$ might also provide evidence for migration of Nasca peoples from Taruga and Nasca river valleys. Looking to distance themselves from imperial Wari settlements, migrants from other river valley settlements may have converged into the most southern valleys of the Rio Grande de Nasca. The bone carbonate of these individuals may differ due to variation in environmental factors which affect water sources in higher elevated valley systems.

If there is no variation in $\delta^{18}O$, one explanation could be that puquios were built such that water had very little exposure to evaporation in the lowland environment. The puquios were constructed to bring subterranean water to the surface where it is expected exposure to evaporation in the valleys would alter $\delta^{18}O$. Open trench puquios and surface reservoirs that are typical of Las Trancas Valley and southern tributaries (Silverman, 2002) would most likely allow for evaporation. Water brought to the surface by the puqios would be stored and possibly conserved in reservoirs. This would extend the time water was exposed to lowland valley environment and increase the likelihood that evaporation occurs. However, if $\delta^{18}O$ values are uniform it would be expected that

subterranean water when brought to the surface was not exposed to surface environment for a long enough period for evaporation to occur.

MATERIALS AND METHODS

Bone samples from six-five adult human skeletons of the 1927-1928 Julio C. Tello Nasca skeletal collection were analyzed in this study. Curated at the Museo Nacional de Arqueologia, Antropologia, e Historia del Peru in Lima, Peru, these burials were originally from three cemeteries located within 10 km from each other in the southernmost Las Trancas valley of the SNR (Novoa Bollota, 2002). These cemeteries including individuals from the entire Nasca sequence (Table 1), but are not associated with specific Nasca sites. They are, however, located near the large local site of Huaca del Loro. Forty- eight individuals date from the pre-imperial period and 17 individuals date from the period of imperial influence. Of the individuals designated from pre-imperial there were 11 from Early Nasca, 17 from Middle Nasca, and 20 from Late Nasca. Of the individuals designated from the imperial period there were 13 buried with at least one piece of Wari (i.e. "Chakipampa") style ceramic, and 4 buried with only the local (i.e. "Loro") ceramic style. Two "trophy" head individuals were interred with individuals from the imperial period who were buried with local ceramics.

Relative status was assigned based on tomb ceramic offerings, as was done in earlier Nasca burial studies (Carmichael, 1995; Kellner and Schoeninger, 2007). Many of the tombs had individuals who were buried with imperial style ceramics. Some tombs contained single individuals with imperial style ceramics. Some tombs were re-used, with various parts of previous burials moved for newer burials or offerings (Novoa Bollota, 2002; Kellner and Schoeninger, 2007). The living status of "trophy" head individuals is impossible to determine. Only the status of the primary burial with whom they are buried is known. High status individuals are more likely to posses "trophy"

head individuals as burial objects than lower status individuals (Carmichael, 1995).

Prior to analysis bone material was manually cleaned to remove any surface contamination. FTIR spectra were obtained for untreated bone samples to assess the possibility of diagenetic alteration. CI for all samples is low (< 3.8) (Table 3). This indicates that diagenesis, which would alter the chemical composition of the bone, has not occurred. Bone samples were ground using mortar and pestle. Approximately 20 mg of bone powder was collected from 200 mesh (75 microns) screen. Each sample was soaked in a .1M standard bleach solution for 24 hr. The powder was rinsed three times with distilled water and then soaked in a dilute (0.25 M) solution of acetic acid for 24 hours followed by another three water rinses to remove exogenous calcite. The remaining material was dried and 2-3 mg of bone powder was then analyzed with an Isotope Ratio Mass Spectrometer (IRMS). All analyses were performed by the Laboratory for Stable Isotope of Science at Scripps Institute of Oceanography. Samples are placed in a sample chamber designed so that helium is directed over the sample surface. A CO_2 laser pulse heats a spot on the sample surface, which causes decarbonation and evolution of CO_2 into the helium stream. The CO_2 passes through a gas chromatograph (GC) and into an IRMS, where ^{13}C and ^{18}O values are measured simultaneously (Matthews and Hayes, 1978). Oxygen-isotope ratios ($\delta^{18}O$) are reported in standard delta (δ) notation and measured relative to the VSMOW standard (Vienna Standard Mean Ocean Water). All values are expressed in parts per thousand ($^{o}/_{oo}$) using the following standard formula:

$$\delta^{18}O = \frac{(^{18}O/^{16}O - {}^{18}O \text{ standard})}{(^{18}O/^{16}O \text{ standard})} \quad X \ 1000$$

^{18}O VPDB values were converted to ^{18}O VSMOW values using ^{18}O VSMOW = 1.03091 × ^{18}O VPDB + 30.91. Isotope results have been normalized on the VPDB and VSMOW scales using NBS-18 and NBS-19 calcite standards. The standard deviations for replicate measurements are 0.2‰ and 0.4‰ for ^{18}O and ^{13}C, respectively.

RESULTS

The $\delta^{18}O$ and $\delta^{13}C$ data are presented in Table 3 and Graph 3. Early Nasca samples have a $\delta^{18}O$ mean of 24.1$\pm$ 1.1‰. Middle Nasca has a $\delta^{18}O$ mean of 23.4 $\pm$ 1.2‰ similar to Late Nasca $\delta^{18}O$ mean of 23.1 $\pm$ 1.0 ‰ (Table 4). Middle Nasca and Late Nasca samples are within a 1‰ of Early Nasca. Standard deviations for Early, Middle and Late Nasca are all ⁻1. Comparing Early Nasca $\delta^{18}O$ mean to Imperial Loro or Chakipampa $\delta^{18}O$ mean shows a difference close to 2‰. People buried with local ceramics during the imperial period have $\delta^{18}O$ mean of 23.0 $\pm$ 0.7‰. People buried with Chakipampa ceramics have a $\delta^{18}O$ mean of 22.4 $\pm$ 0.6‰ (Table 4). Standard deviation for Imperial samples is < 1.

$\delta^{18}O$ values of bone carbonate are increasingly negative through time. (Table 3) There does not appear to be a significant difference between individuals buried with Loro (23.0 $\pm$ 0.7‰) or Chakipampa (22.4 $\pm$ 0.6‰) style ceramics (Table 4). It is important to note, however, that the Loro sample size is small. Comparing $\delta^{18}O$ of pre-imperial to imperial (Table 5) does show a significant difference particularly when comparing individuals from Early Nasca to individuals buried with Chakipampa style ceramics from the Imperial Period**.**

DISCUSSION

An unreliable water source during pre-imperial periods might account for the marked degree of variability seen. Prior to the construction of the puqio it is suggested that short canals were constructed to divert water from rivers, however, there are no clear examples of irrigation systems before the construction of puqios (Schreiber and Rojas, 1992). Due to the degree of agriculture present in the Las Trancas Valley, year-round habitation would not have been possible without some sort of irrigation (Schreiber and Rojas, 1992). Obtaining water would have been more difficult and might have increased movement or migration to areas of higher elevation. Water accessibility in the Upper Valley (above 1200 meters) for example would be easier due to year round access to surface rivers. These water sources would have $\delta^{18}O$ that are different due to altitudinal changes, and would be reflected in the variation seen within pre-imperial populations.

A high level of variation is seen across all pre-imperial periods. Broad variation might indicate biological variation within sample group; however, the degree of variability would be extreme because of human endothermic physiology. A narrow range of $\delta^{18}O$ variation seen during Imperial contact would be expected in human populations with reduced mobility due to a centralized water source. The construction and use of puqios not only allowed individuals to live in the Las Trancas Valley year round, but provided a centralized source to obtain water (Schreiber and Lancho Rojas, 2003). Use of these puqios as a consistent water source during Imperial time is assumed and further supported by $\delta^{18}O$ seen in individuals buried with Loro and Chakipampa ceramics.

Increasing negative $\delta^{18}O$ values of bone carbonate during the Imperial period compared to pre-imperial could suggest the presence of individuals from other areas with water sources at higher altitudes. Changes $\delta^{18}O$ occur at a rate of close to 0.28 ‰ for every 100 meters for elevations under 5000 meters (Poage and Chamberlain, 2001). Bone carbonate $\delta^{18}O$ values of individuals buried during imperial period in Las Trancas Valley cemeteries (elevation 725 m) have mean $\delta^{18}O$ values that are increasingly negative (Chakipampa- 22.4 $\pm$ 0.6‰; Loro- 23.0 $\pm$ 0.7‰) compared to pre-imperial (Early- 24.1$\pm$ 1.1‰; Middle- 23.4 $\pm$ 1.2‰; Late- 23.1 $\pm$ 1.0 ‰). This suggests that during the Imperial period individuals from higher elevations (over 800 meters) could have been migrating into Las Trancas Valley. However, if individuals from highland sierra regions (over 2000 meters) were buried in Las Trancas Valley it would be expected that the $\delta^{18}O$ would be differentially negative compared to local Nasca populations.

CONCLUSION

The oxygen isotope data presented here provides support for the possible presence of individuals from higher elevations migrated to lower regions of the Las Trancas Valley. This suggests that the presence of foreign born individuals in the SNR, but does not necessarily lend support to the presence of Wari emissaries. As Wari expanded down into the northern valleys of the Rio Grande de Nasca, Nasca settlements disappear and are replaced by Wari administration centers. Subsequently, Nasca settlements appear in the Las Trancas Valley with significantly larger populations. Puqios were probably a major contributing factor to the population expansion seen during the Late Nasca period (Schreiber, 1992) and into the Imperial period. The Las Trancas Valley based on isotopic analysis does not appear to be a Wari administration center, but could be under the control of Nasca elite.

If the Wari were not sending emissaries Nasca elite of Huaca del Loro still had contact with the Wari Empire. In an attempt to maintain contact, the Wari could have gained some amount of political domination in the area without using direct control or force through acculturation. Wari ceramics and textiles might symbolize the prestige or power the Wari elite have given the Nasca elite. This would be similar to the Pukara and Paracas-Nasca-style artifacts found in elite mortuary sites in Moquegua (Goldstein, 2000) Another example would be the Nasca elites themselves who maintained indirect authority in surrounding regions by hosting feasts at Nasca ceremonial centers (Schreiber, 1992). These ceremonial sites, like burial ceramics and textiles, represent the economic, political and ideological power of the dominant culture (Silverman, 1993; Vaughn, 2005).

Further research should include a more thorough examination of people buried with Loro ceramics during the Imperial Period. A larger sample needs to be analyzed from this period for a more accurate depiction of $\delta^{18}O$ variation during the time of Wari contact. While sociopolitical control in Huaca del Loro was most likely not Wari, it is unclear who was in control of Las Trancas Valley. The Nasca from northern valleys could have migrated to Las Trancas Valley and assumed control. However, the local Nasca who had established control in Huaca del Loro prior to the Imperial period most likely remained in power. Examining what kind of sociopolitical impact Nasca migrants had in the Las Trancas Valley is an important question requiring future research.

APPENDIX

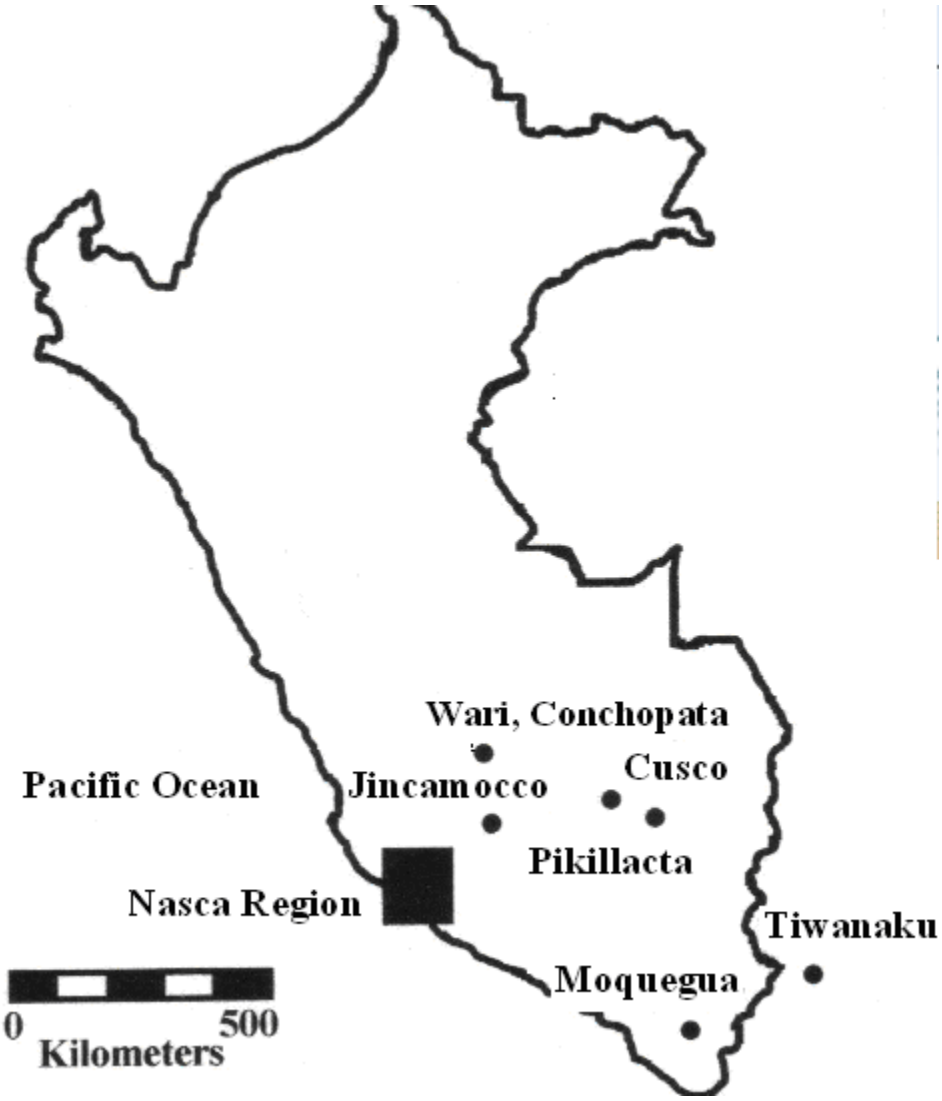


Figure 1: Map of Peru. Showing location of Nasca region, Wari- Conchopata Jincamocco, Cusco, Pikillacta, Moquegua, and Tiwanaku

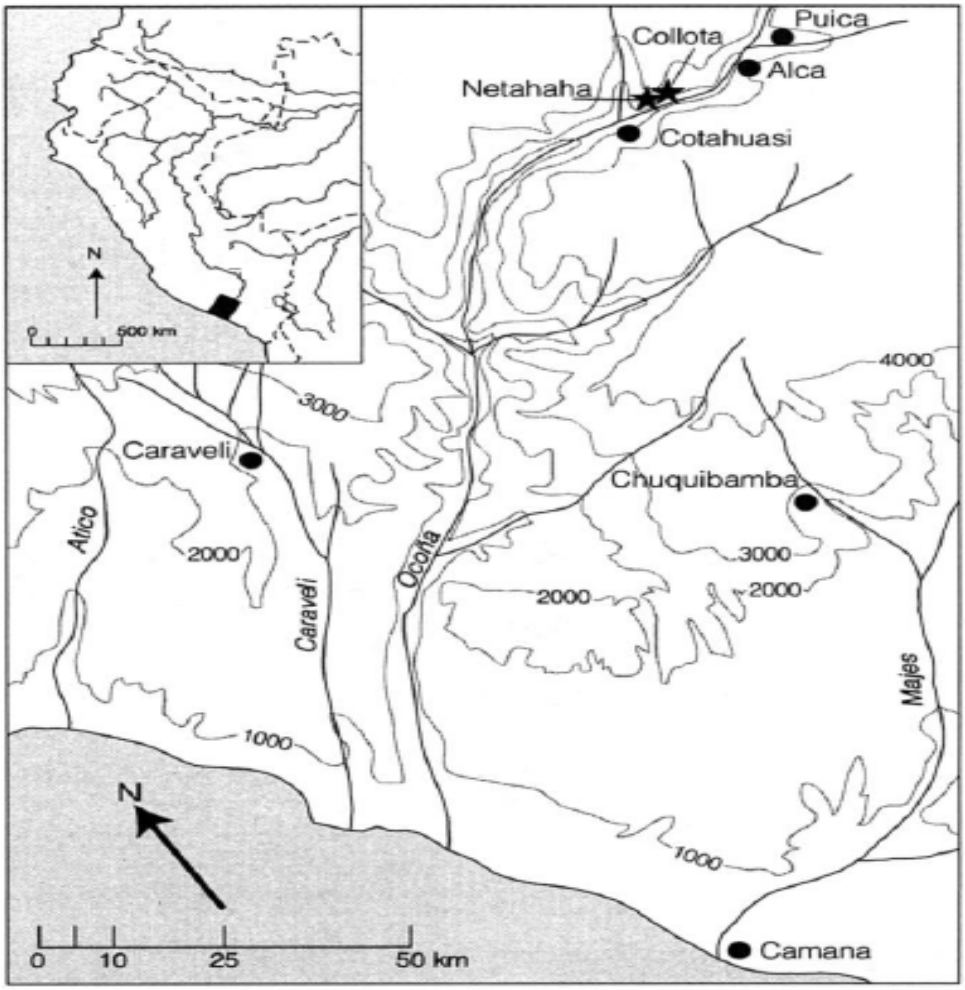


Figure 2: The Cotahuasi Valley- Collota and Netahaha located in the uppermost portion of the drainage. The solid area on the inset map of Peru indicates the location of the drainage.

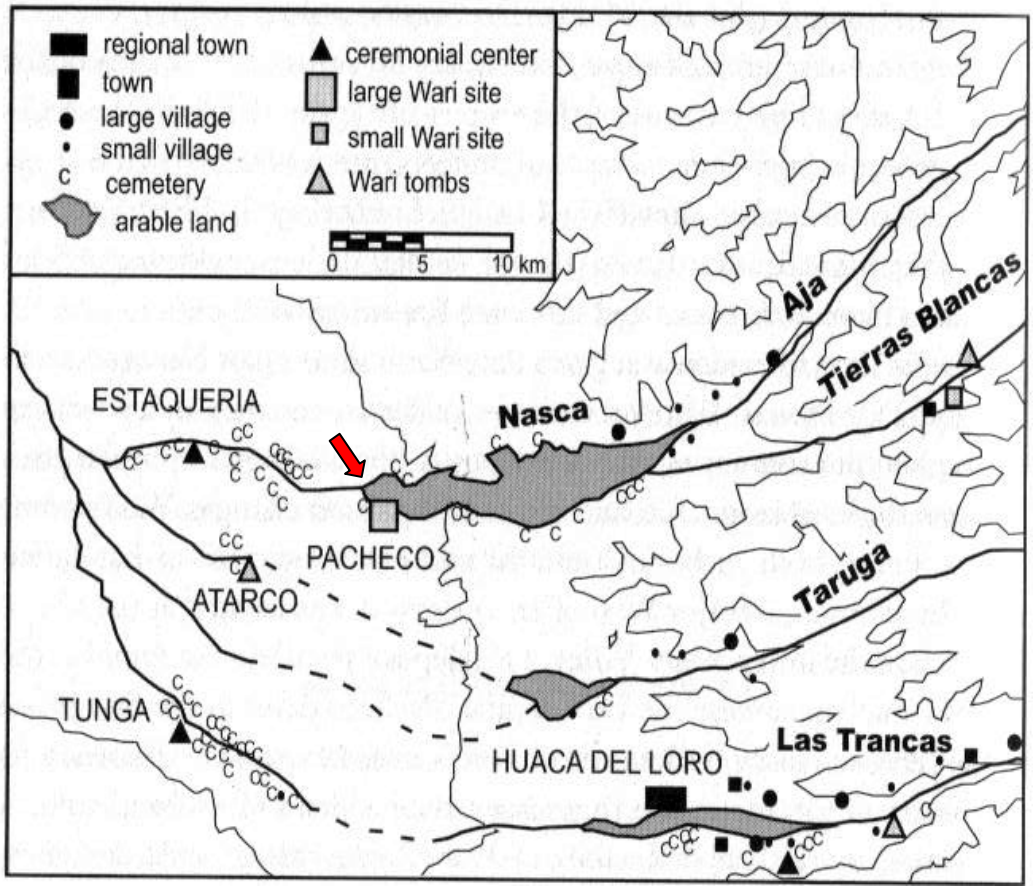
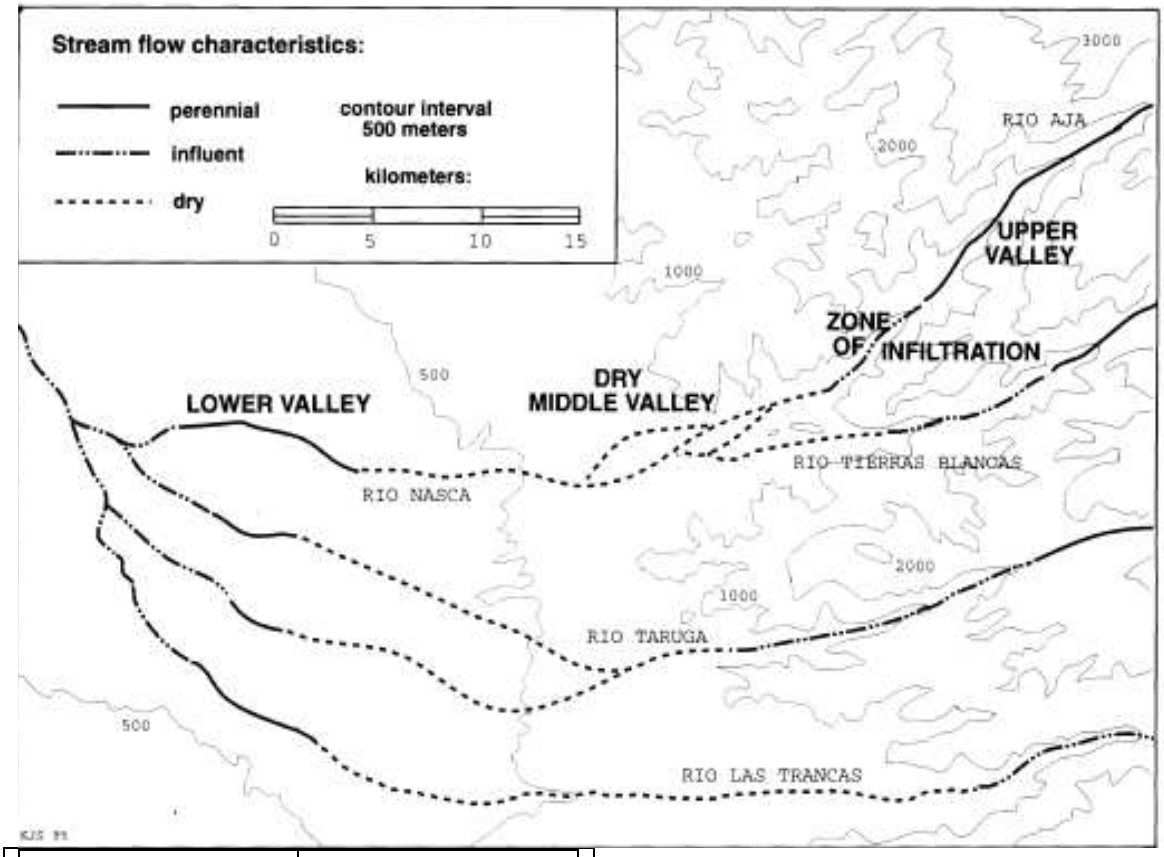


Figure 3: Settlement patterns of the SNR during Wari occupation in Middle Horizon (Conlee and Schreiber, 2006)



Valleys	Elevations
Sierra	*Above 2000 m*
Upper Valley	*1200 to 2000 m*
Zone of Infiltration	*800 to 1200 m*
Middle Valley	*400 to 800 m*
Lower Valley	*Below 400 m*
Tierras Blancas	*850 m*
Taruga	*625 m*
Las Trancas	*725 m*

Figure 4: Perennial, Influent and Dry Stream flow Characteristics; Elevation of Nasca, Taruga, Las Trancas and Tierras Blancas valleys. Elevation of valley subdivisions (Schreiber and Rojas, 1995)

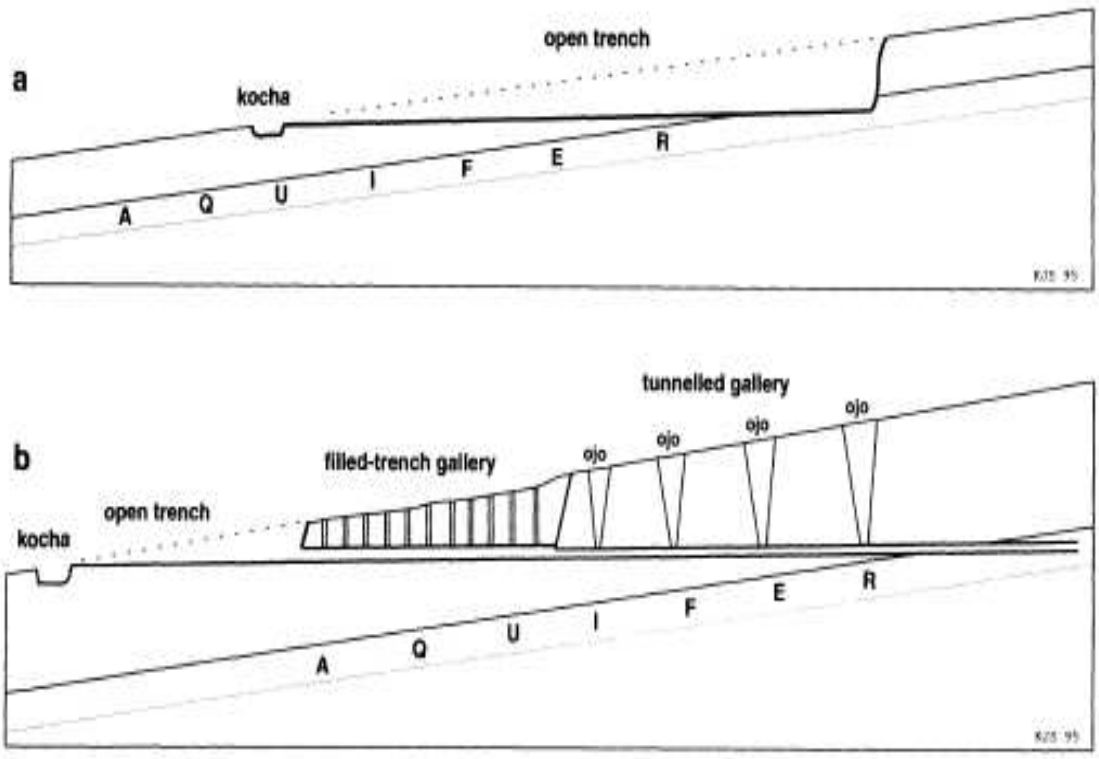


Figure 5: Cross section of a trench-type puquios (top) and a gallery-type puquios (bottom) (Schreiber and Rojas, 1995)

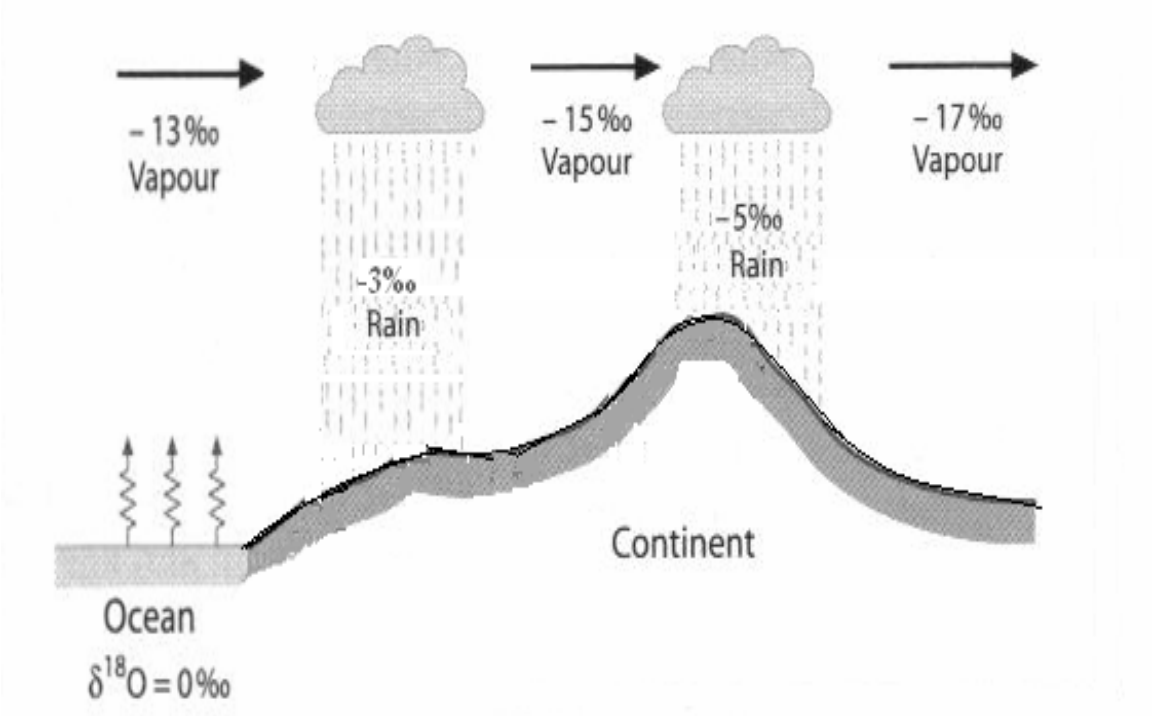


Figure 6: Schematic O-isotope fractionation of water in the atmosphere (Adapted from Hoefs, 2004)

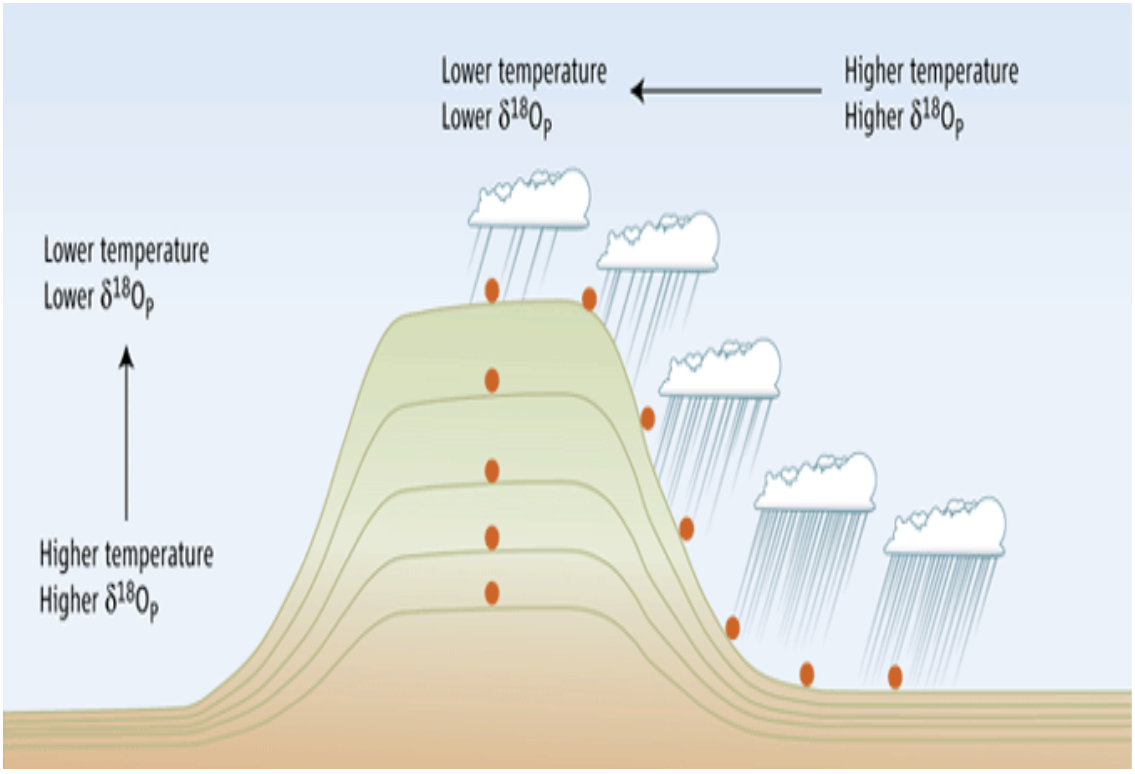


Figure 7: Mountain ranges cause air masses to rise and lose moisture. A gradient exists between warmer temperatures and higher $\delta^{18}O$ values at lower elevations to cooler temperatures and lower $\delta^{18}O$ values at higher elevations. (Poage and Chamberlain, 2006)

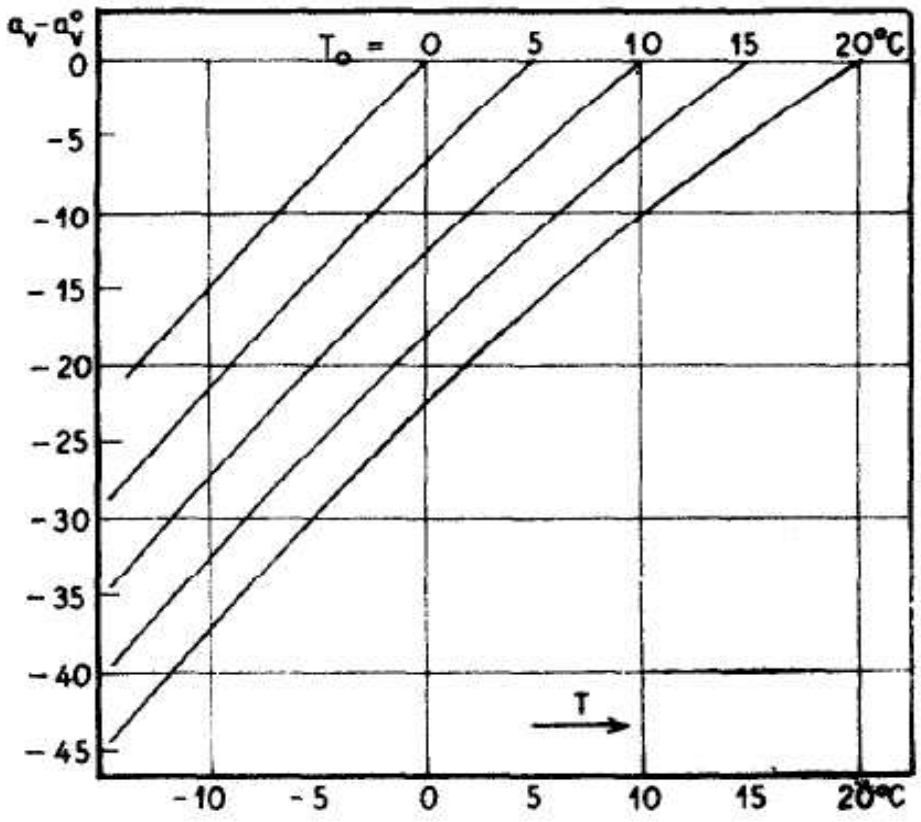


Figure 8: The increase in ^{18}O abundance in a quantity of vapor from which water has been separated by cooling from T_0 to T (Dansgaard, 1964).

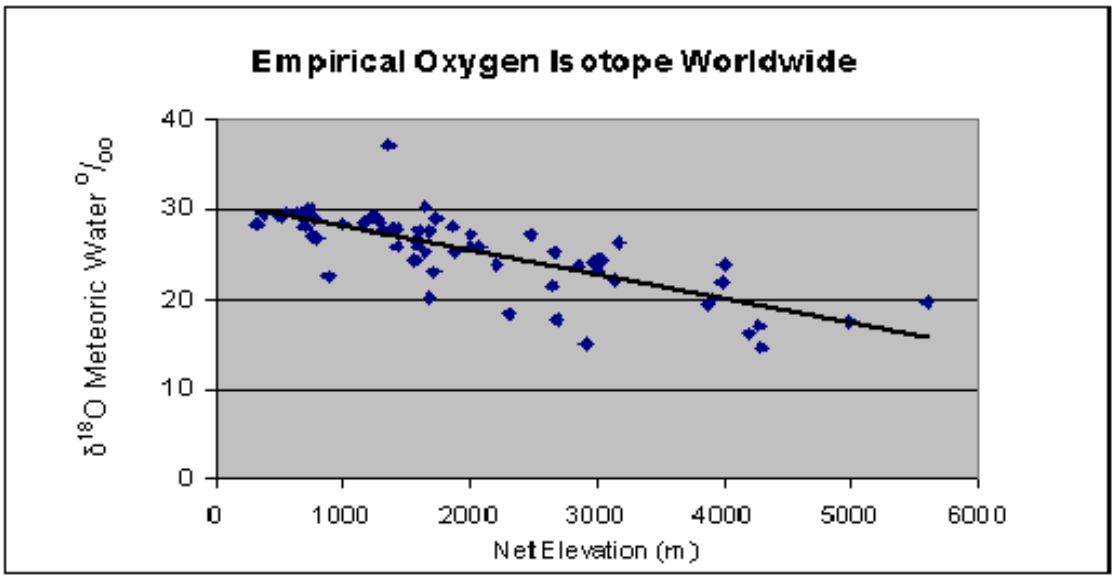


Figure 9: $\delta^{18}O$ (VSMOW) from precipitation and Water Sources worldwide (Poage and Chamberlain, 2001)

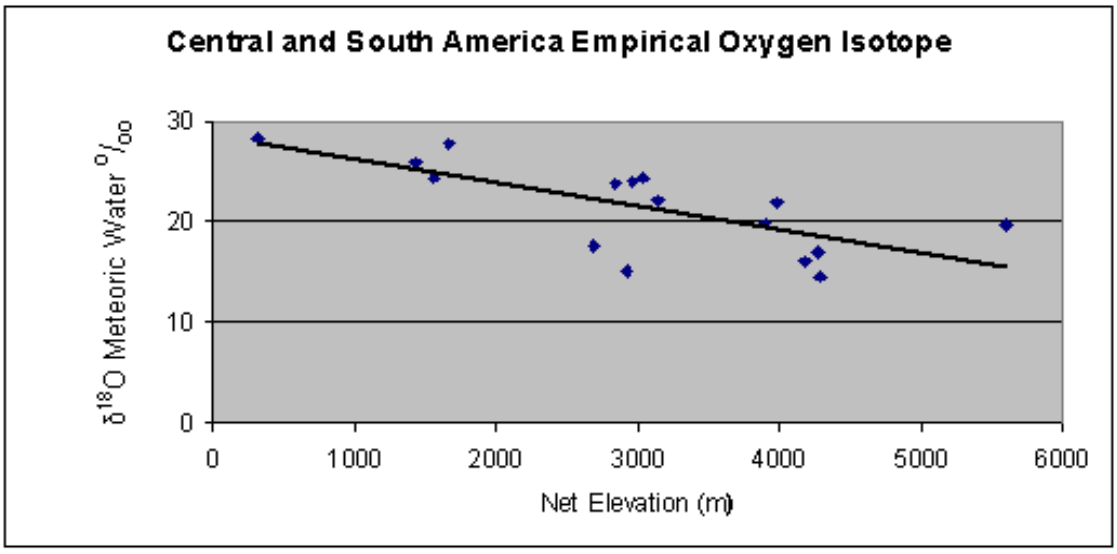


Figure 10: $\delta^{18}O$ (VSMOW) from precipitation and water sources of Central and South America. (Poage and Chamberlain, 2001)

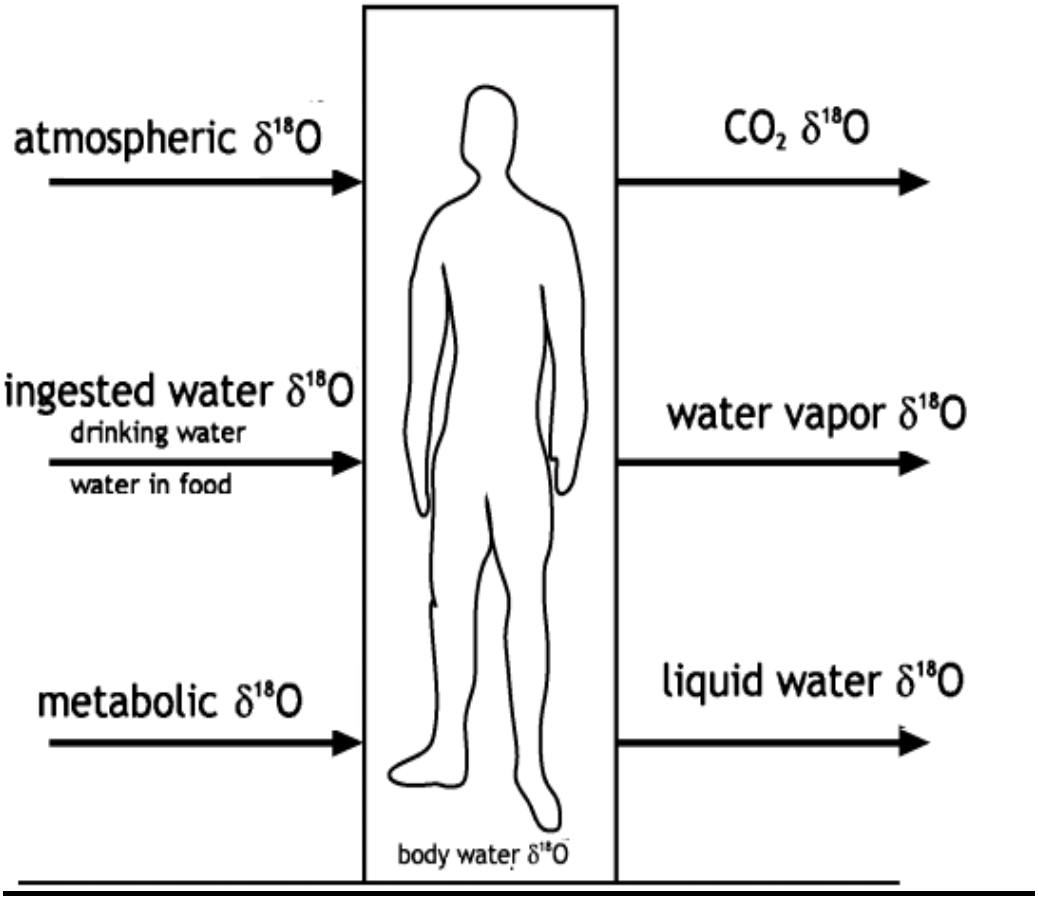


Figure 11: Fluxes of oxygen contributing to isotopic ratio of body water reservoir

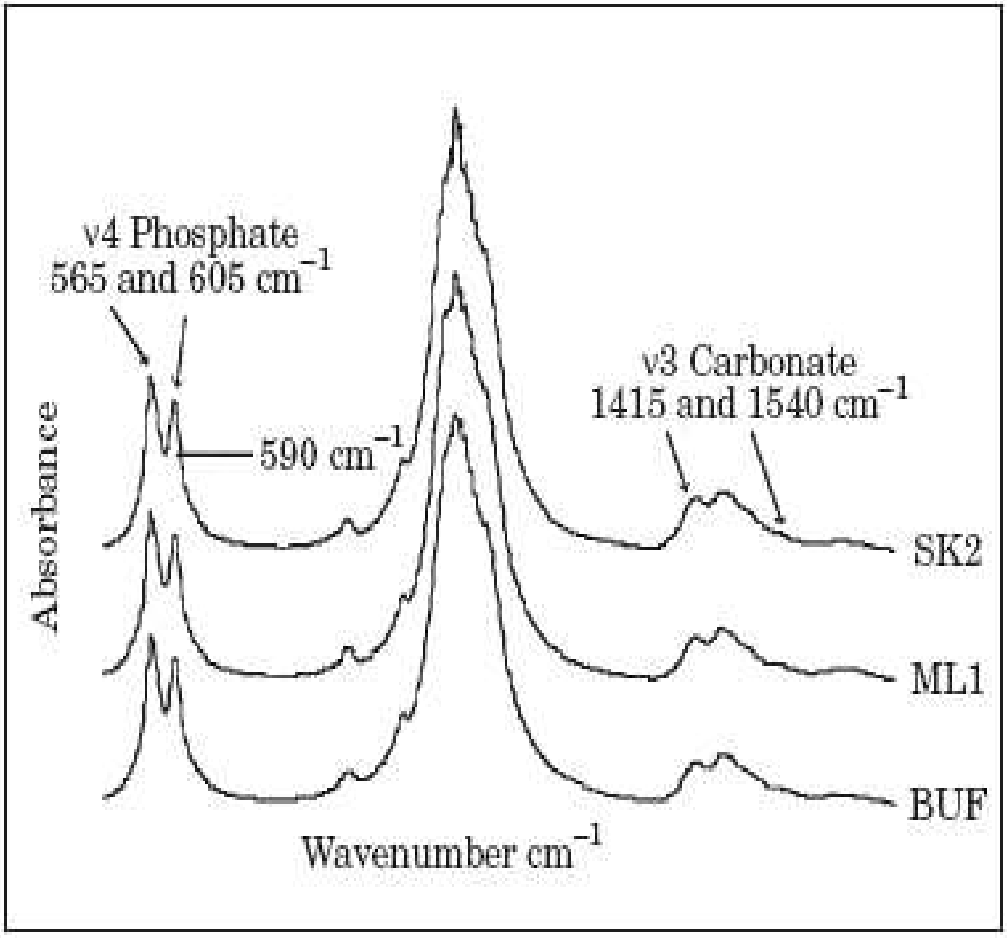


Figure 12: FTIR spectra showing location of absorption bands (Sponheimer and Lee-Thorp, 1999)

Table 1: Chronology of the South Coast of Peru

Horizons and Intermediate Periods	Culture	Approximate dates
Late Horizon	Inca	A.D. 1476-1532
Late Intermediate	Tiza	A.D. 1000-1476
Middle Horizon	Wari/Loro	A.D. 750-1000
Early Intermediate	Late Nasca	A.D. 550-750
	Middle Nasca	A.D. 450-550
	Early Nasca	A.D. 1-450
Early Horizon	Proto Nasca	100 B.C.- A.D. 1
	Paracas	800-100 B.C.
Initial Period		1800- 800 B.C.
Archaic		9000-1800 B.C.

Table 2: $\delta^{18}O$ (VSMOW) from precipitation and water sources of Central and South America. (Poage and Chamberlain, 2001)

$\delta^{18}O$ Meteoric Water ‰- Central and South America			
Location	Elevation (m)	Oxygen (VPDB)	Oxygen (VSMOW)
Central Chile	4279	-13.5	16.99
Andes, Chile	4186	-14.4	16.06
Northern Chile	2840	-7	23.69
Chile	4291	-15.8	14.62
Argentina	3919	-15.3	15.14
Argentina	3685	-12.9	17.61
Amazon Basin, Andes	5600	-11	19.57
Andes, Chile	2966	-6.7	24.00
Bolivia	3906	-10.7	19.88
Ecuador	3032	-6.3	24.42
Ecuador	3144	-8.5	22.15
Ecuador	3981	-8.7	21.94
Nicaragua	1675	-3.1	27.71
Cordillera Blance, Peru	4980	-13	17.51
Cordillera Blance, Peru	2000	-3.7	27.10
Cordillera Blance, Peru	4005	-6.8	23.90

Table 3: Period, Catalogue Number, Crystallinity Index [CI=(A_{605} + A_{565})/ A_{595}] and Isotope Values of $\delta^{18}O$ ($^{o}/_{oo}$SMOW) and $\delta^{13}C$ ($^{o}/_{oo}$PDB) of Bone Carbonate

Period	Number	CI	$\delta^{18}O$ ($^{o}/_{oo}$SMOW)	$\delta^{13}C$ ($^{o}/_{oo}$PDB)
Early Nasca	20	2.1	25.93	-6.30
Early Nasca	22	1.8	22.58	-9.95
Early Nasca	35	1.9	22.84	-10.64
Early Nasca	43	1.7	24.34	-7.91
Early Nasca	47	1.7	23.50	-10.37
Early Nasca	92	1.4	25.40	-9.96
Early Nasca	95	1.9	23.43	-10.77
Early Nasca	99	1.9	23.41	-10.21
Early Nasca	126	2.1	25.17	-10.38
Early Nasca	129	2.2	24.64	-10.10
Early Nasca	130	2.1	23.83	-10.41
			22.58- 25.93	
Middle Nasca	24	1.8	22.10	-8.12
Middle Nasca	25	1.8	23.52	-8.29
Middle Nasca	31	1.7	20.20	-5.90
Middle Nasca	32	1.9	23.41	-9.06
Middle Nasca	46	1.8	24.09	-8.19
Middle Nasca	55	1.7	24.42	-9.31
Middle Nasca	56	1.7	25.23	-9.38
Middle Nasca	67	1.5	23.22	-7.78
Middle Nasca	68	1.9	23.35	-8.53
Middle Nasca	81	1.6	23.95	-8.74
Middle Nasca	107	1.7	25.77	-8.05
Middle Nasca	110	1.7	22.98	-9.80
Middle Nasca	133	1.8	23.36	-10.14
Middle Nasca	134	1.9	22.78	-9.37
Middle Nasca	135	1.6	22.84	-9.17
Middle Nasca	136	1.7	23.02	-9.67
Middle Nasca	141	1.7	23.65	-8.66
			18.65- 25.77	

Table 3: Period, Catalogue Number, Crystallinity Index, and Isotope Values of $\delta^{18}O$ and $\delta^{13}C$ of Bone Carbonate, Continued

Late Nasca	1	1.6	23.99	-7.98
Late Nasca	2	2.2	23.86	-7.79
Late Nasca	3	2.1	24.15	-5.58
Late Nasca	4	2.0	21.21	-8.94
Late Nasca	5	1.9	23.42	-6.97
Late Nasca	6	1.9	21.95	-8.13
Late Nasca	30	1.7	22.91	-8.46
Late Nasca	36	1.9	22.47	-8.77
Late Nasca	38	1.9	24.54	-7.41
Late Nasca	42	1.7	24.44	-8.22
Late Nasca	74	1.6	23.82	-7.08
Late Nasca	94	1.9	22.67	-11.41
Late Nasca	114	1.9	20.77	-8.12
Late Nasca	115	1.4	24.13	-8.78
Late Nasca	116	1.4	22.16	-8.66
Late Nasca	166	1.7	23.42	-5.96
Late Nasca	168	1.7	22.86	-8.01
Late Nasca	171	1.8	23.54	-8.98
Late Nasca	175	1.9	23.34	-8.86
Late Nasca	180	1.8	23.07	-8.47
			20.77- 24.54	
Imperial (Loro)	10	2.0	22.89	-7.45
Imperial (Loro)	11	1.9	22.07	-8.72
Imperial (Loro)	12	1.8	23.41	-8.71
Imperial (Loro)	33	1.9	23.54	-9.25
			22.07- 23.54	
Imperial (Chakipampa)	13	1.7	23.10	-8.53
Imperial (Chakipampa)	14	1.8	22.77	-8.92
Imperial (Chakipampa)	15	2.0	21.50	-9.03
Imperial (Chakipampa)	17	2.0	21.99	-8.13
Imperial (Chakipampa)	18	1.5	22.29	-9.62

Table 3: Period, Catalogue Number, Crystallinity Index, and Isotope Values of $\delta^{18}O$ and $\delta^{13}C$ of Bone Carbonate, Continued

Imperial (Chakipampa)	52	1.7	21.40	-10.01
Imperial (Chakipampa)	53	1.9	22.43	-8.12
Imperial (Chakipampa)	85	1.6	21.91	-8.64
Imperial (Chakipampa)	93	1.4	22.69	-8.04
Imperial (Chakipampa)	260	1.8	22.08	-8.86
Imperial (Chakipampa)	262	1.3	22.51	-7.23
Imperial (Chakipampa)	264	1.8	23.47	-7.93
Imperial (Chakipampa)	265	1.8	22.78	-7.90
			21.40- 23.47	

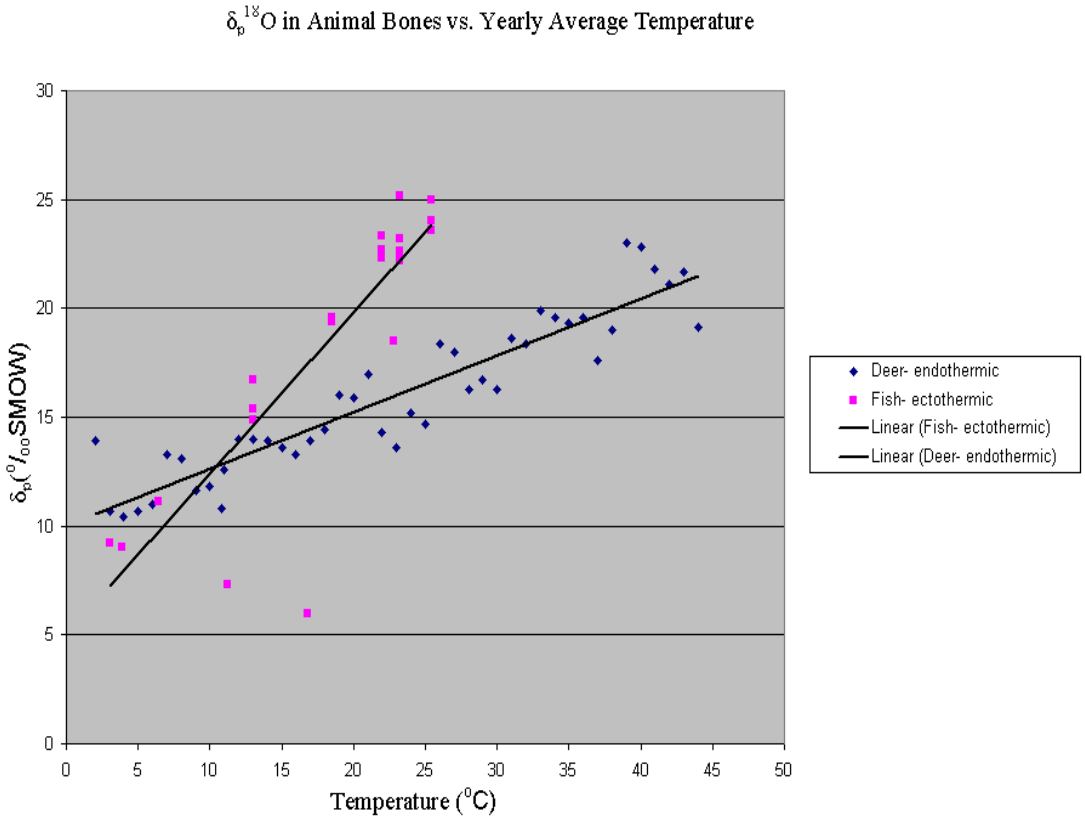
Table 4: Mean and Standard Deviation for each time period

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Early Nasca	11	24.0973	1.08576	.32737	23.3678	24.8267	22.58	25.93
Middle Nasca	17	23.4053	1.22083	.29609	22.7776	24.0330	20.20	25.77
Late Nasca	20	23.1360	1.03197	.23076	22.6530	23.6190	20.77	24.54
Imperial (Loro)	4	22.9775	.66700	.33350	21.9162	24.0388	22.07	23.54
Imperial (Chakipampa)	13	22.3785	.60139	.16679	22.0150	22.7419	21.40	23.47
Total	65	23.2078	1.11920	.13882	22.9305	23.4852	20.20	25.93

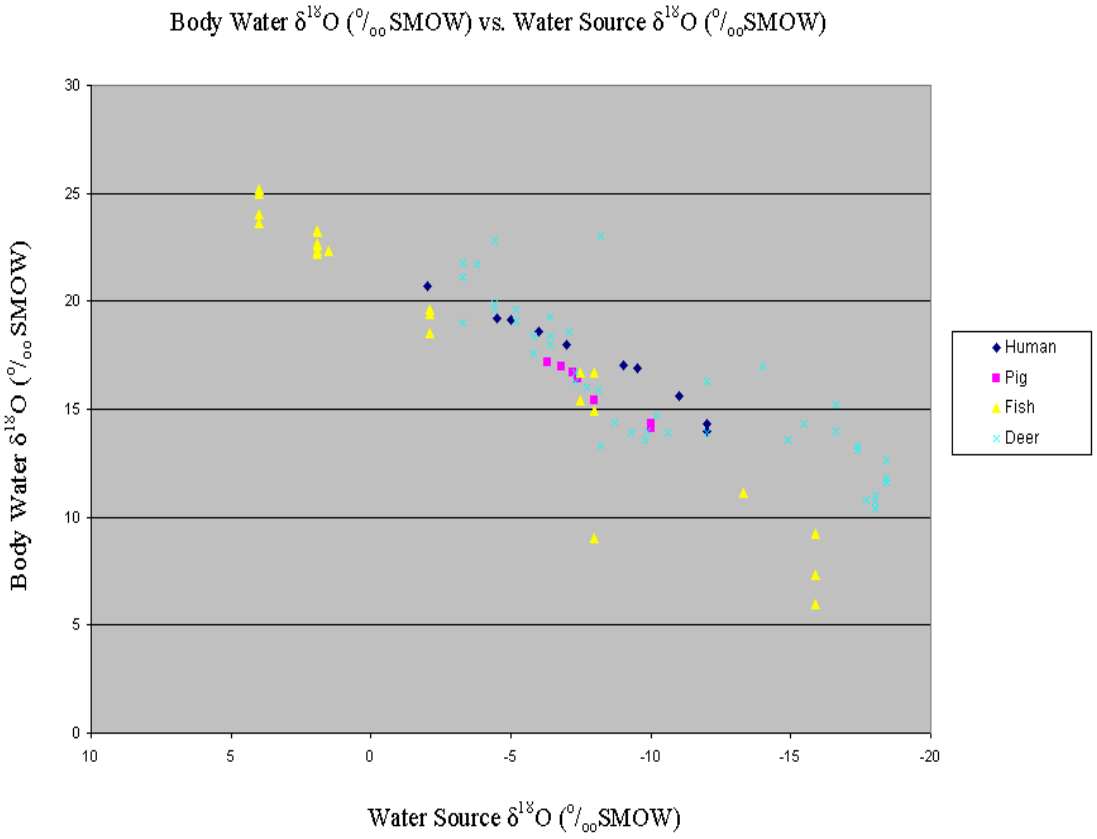
Table 5: Multiple Comparisons Tukey HSD.
* The mean difference is significant at the .05 level

		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
(I) PERIOD#	**(J) PERIOD#**				**Lower Bound**	**Upper Bound**
Early Nasca	Middle Nasca	.6920	.39190	.403	-.4102	1.7942
	Late Nasca	.9613	.38018	.098	-.1080	2.0305
	Imperial (Loro)	1.1198	.59134	.332	-.5433	2.7829
	Imperial (Chakipampa)	1.7188*	.41491	.001	.5519	2.8857
Middle Nasca	Early Nasca	-.6920	.39190	.403	-1.7942	.4102
	Late Nasca	.2693	.33410	.928	-.6704	1.2089
	Imperial (Loro)	.4278	.56283	.941	-1.1551	2.0107
	Imperial (Chakipampa)	1.0268	.37315	.058	-.0226	2.0763
Late Nasca	Early Nasca	-.9613	.38018	.098	-2.0305	.1080
	Middle Nasca	-.2693	.33410	.928	-1.2089	.6704
	Imperial (Loro)	.1585	.55473	.999	-1.4016	1.7186
	Imperial (Chakipampa)	.7575	.36082	.234	-.2572	1.7723
Imperial (Loro)	Early Nasca	-1.1198	.59134	.332	-2.7829	.5433
	Middle Nasca	-.4278	.56283	.941	-2.0107	1.1551
	Late Nasca	-.1585	.55473	.999	-1.7186	1.4016
	Imperial (Chakipampa)	.5990	.57908	.838	-1.0296	2.2277
Imperial (Chakipampa)	Early Nasca	-1.7188*	.41491	.001	-2.8857	-.5519
	Middle Nasca	-1.0268	.37315	.058	-2.0763	.0226
	Late Nasca	-.7575	.36082	.234	-1.7723	.2572
	Imperial (Loro)	-.5990	.57908	.838	-2.2277	1.0296

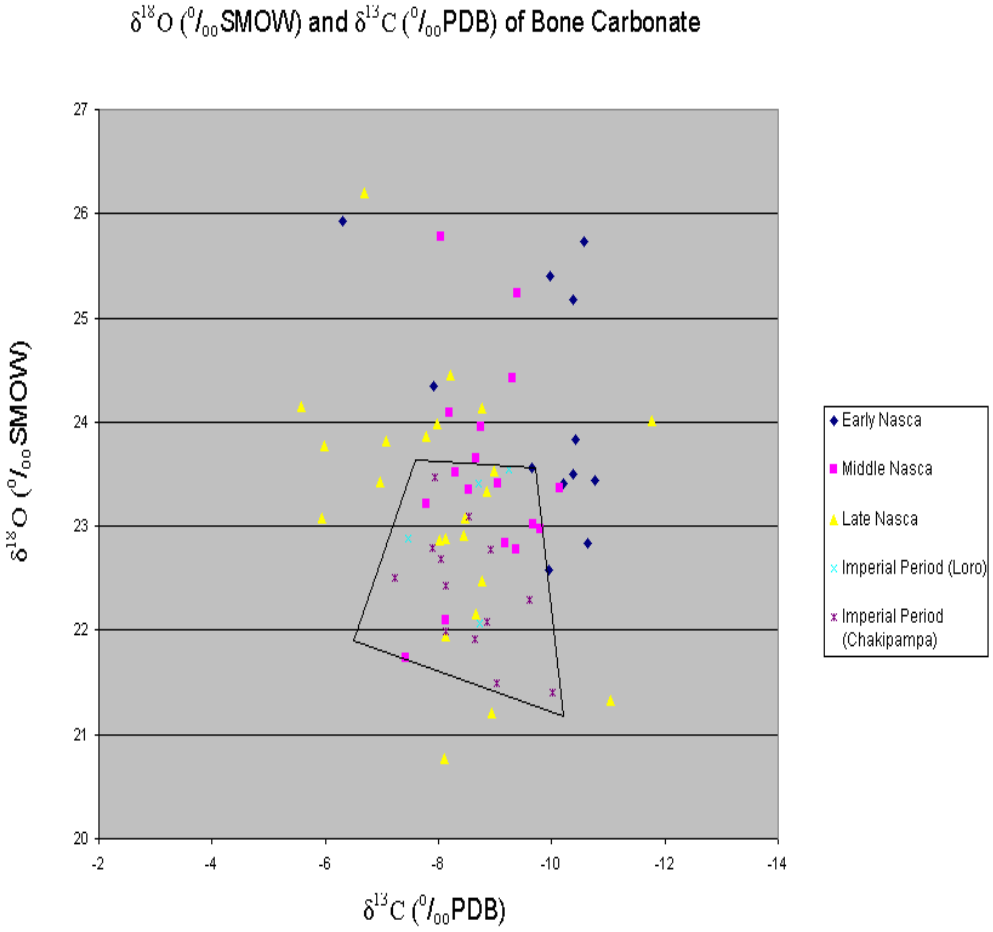
Graph 1: Plot of $\delta_p{}^{18}O$ ($^o/_{oo}$ SMOW) of deer and fish bones against yearly average Temperature (Luz et al, 1990; Koldodny et al, 1983)



Graph 2: Linear distribution of Body Water $\delta_p{}^{18}O$ ($^o/_{oo}$ SMOW) and Water Source $\delta^{18}O$ ($^o/_{oo}$SMOW) for fish, pig, human, and deer (Kolodny et al, 1983; Longinelli, 1984, Luz et al, 1990)



Graph 3: Plot of $\delta^{18}O$ ($^{o}/_{oo}$SMOW) and $\delta^{13}C$ ($^{o}/_{oo}$PDB) of Bone Carbonate from (Early, Middle, Late) Nasca period and (Loro and Chakipampa) Imperial period



REFERENCES

Aveni, A., 1990. *The Lines of Nasca*. American Philosophical Society, Philadelphia.

Ayliffe, L.K. and A.R. Chivas., 1990. Oxygen Isotope Composition of the Bone Phosphate of Australian Kangaroos: Potential as a Paleoenvironmental Recorder. *Geochimica et Cosmochimica Acta.* 54: 2603-2609.

Barrick, R, Fischer, A., Kolodny, Y., Luz, B., and Bohaska, D. 1992. Cetacean bone oxygen isotopes as proxies for Miocene ocean composition and glaciation. *Palaios*, 7 (5): 521-531.

Bonar, L. C., Shimizu,M., Roberts, J. E., Griffin, R. G. & Glimcher, M. J. 1991. Structural and composition studies on the mineral of newly formed dental enamel: a chemical, x-ray diffraction, and ^{31}P and proton nuclear magnetic resonance study. *Journal of Bone and Mineral Research* 6, 1167–1176.

Bowen GJ, Wilkinson B., 2002. Spatial distribution of $\delta^{18}O$ in meteoric precipitation. *Geology.* 30: 315–318.

Bryant, J.D., and Froelich, P.N., 1995. A model of oxygen isotope fractionation in body water of large mammals. *Geochimica et Cosmochimica Acta.* 59: 4523-4537.

Bryant, J.D., and Froelich, P.N. 1996. Oxygen Isotope Composition of Human Tooth Enamel from Medieval Greenland: Linking Climate with Society: Comment. *Geology*, 24: 477-478.

Bryant, J.D., Koch, P.L., Froelich, P.N., Showers, W.J., Genna, B.J., 1996. Biologic and Climatic Signals in the Oxygen Isotope Composition of Eocene- Oligocene Equid Enamel Phosphate. *Palaeogeography, Palaeoclimatology, Palaeoecolog. 1:* 75-89.

Budd, P., Millard, A., Chenery, C., Lucy, S., Roberts, C., 2004. Investigating population movement by stable isotope analysis: a report from Britain. *Antiquity.* 78: 127-141.

Carmichael, P., 1995. Nasca Burial Patterns: Social Structure and Mortuary Ideology. In: Dillehay, T., (Ed.), Tombs for the Living: Andean Mortuary Practices, pp. 161-187.

Chamberlain, C.P., and Poage, M.A. 2000. Reconstructing the paleotopography of mountain belts from the isotopic composition of authigenic minerals: *Geology*. 28: 115-118.

Chamberlain, M.A., and Poage, C.P. 2001. Empirical Relationships Between Elevation and the Stable Isotope Composition of Precipitation and Surface Waters: Considerations for Studies of Paleoelevation Change. *American Journal of Science*. 301: 1-15.

Conlee, C.A. and Schrieber, K. 2006. The Role of Intermeidate Elites in the Balkanization and Reformation of Post-Wari Society in Nasca, Peru. In Elson, C.M. and Covey, A., (eds) *Intermediate Elites in Pre-Columbian States and Empires*, The University of Arizona Press, 94-111.

Cossins, A. R. and K. Bowler., 1987. *Temperature biology of animals*. Chapman & Hall, New York, New York.

D'Altroy, T.N., and Hastorf, C.A., 2001. *Empire and Domestic Economy*. Kluwar Academic/Plenum Publishers, New York.

D'Angela, D. and Longinelli, A. 1990. Oxygen Isotopes in Living Mammal's Bone Phosphate: Further Results. *Chemical Geology* (Isotope Geosciences Section), 86: 75-82.

Dansgaard, W. 1964. Stable isotopes in precipitation: *Tellus*. 16: 436-468. Doyle, M.W. 1986. Empires. Ithaca: Cornell University Press. Gat JR., 1996. Oxygen and hydrogen isotopes in the hydrologic cycle. *Annual Review of Earth and Planetary Science*. 24: 225–262.

Goldstein, P., 2000. Exotic goods and everyday chiefs: Long-distance exchange and indigenous sociopolitical development in the south-central Andes. *Latin American Antiquity.* 11: 335-361.

Hoefs., 2004. Stable Isotope Geochemistry. Springer, Berlin.

Iacumin P, Bocherens H, Mariotti A, Longinelli A., 1996. An isotopic palaeoenvironmental study of human skeletal remains from the Nile Valley. *Palaeogeography, Palaeoclimalotology, Palaeoecology*, 126: 15-30

Jennings, J. and Craig, N., 2001. Polity Wide Analysis and Imperial Political Economy: The Relationship between Valley Political Complexity and Administrative Centers in the Wari Empire of the Central Andes, *Journal of Anthropological Archaeology*, 20 (4): 479-502.

Karhu, J., and Epstein, S. 1986. The implication of the oxygen isotope records in coexisting cherts and phosphates. *Geochimica et Cosmochimica Acta*, 50: 1745-1757.

Kellner, CM and Schoeninger, MJ., 2007. Diet during imperial influence in ancient Peru: The impact of the Wari Empire on Nasca populations (AD 750-1000). *American Journal of Physical Anthropology*

Knobloch, P.J. 1976. *A study of the Huarpa Ceramic style of the Andean Early Intermediate Period*. Master's thesis, State University of New York, Binghamton.

Koch, P., Fisher, D.C., Dettman, D., 1989. Oxygen isotope variation in the tusks of extinct proboscideans: a measure of season of death and seasonality. *Geology.* 17: 515-519.

Koch, P.L., Zachos, J.C., Dettman, D.L., 1995. Stable isotope stratigraphy and paleoclimatology of the Paleogene Bighorn Basin, (Wyoming, USA). *Palaeogeography, Palaeoclimatology, Palaeoecology.* 115: 61-89.

Kohn, M.J., 1996. Predicting animals $\delta^{18}O$: Accounting for diet and physiological adaptation. *Geochimica et Cosmochimica Acta.* 60: 4811-4829.

Kohn, M.J., and Cerling, T.E., 2002. Stable isotope compositions of biological apatite. *Reviews in Minerology and Geochemistry*. 48: 455-488.

Kohn, M.J., Schoeninger, M.J., and Valley, J.W. 1996. Herbivore tooth oxygen isotope compositions: effects of diet and physiology. *Geochimica et Cosmochimica Acta.,* 60: 3889-3896.

Kohn, MJ, Mclver, L., 2006. Stable isotope chemistry of fossil bone as a new paleoclimate indicator. *Geochimica et Cosmochimica Acta*. 70: 931-946.

Kolodny, Y, Luz, B., and Navon, O. 1983. Oxygen isotope variations in phosphate of biogenic apatites, I. Fish bone apatite- rechecking the rules of the game. *Earth Planetary Science Letter*, 64: 398-404.

Land, L.S., Lundelius, E.L., and Valastro, S., 1980. Isotopic Ecology of Deer Bones. *Palaeolgeography, Palaeoclimatology, Palaeoecology.* 32: 143-151.

Lane, G.A., Dole, M. 1956. Fractionation of Oxygen Isotopes during Respiration. *Science.* 123: 574-576.

Larsen, C.S., Griffin, M.C., Hutchinson, D.L., Noble, V.E., Norr, L., Pastor, R.F., Ruff, C.B., Russell, K.F., Schoeninger, M.J., Schultz, M., Simpson, S.W., Teaford, M.F., 2001. Frontier of Contact: Bioarchaeology of Spanish Florida. *Journal of World Prehistory*. 15: 135-147.

Levison, A.A., Luz, B., and Kolodny., 1987. Variations in oxygen isotopic compositions of human teeth and urinary stones. *Applied Geochemistry.* 2: 367-371.

Leonard, F., and R.J. Scullin. 1969. New Mechanism for Calcification of Skeletal Tissues. *Nature.* 224: 1113-1115.

Longinelli, A. 1984. Oxygen isotopes in mammal bone phosphate: a new tool for paleohydrological and paleoclimatological research. *Geochimica et Cosmochimica Acta.* 48: 385–390.

Longinelli, A., and Nuti, S., 1973. Revised phosphate-water isotopic temperature scale: *Earth and Planetary Science Letter*, 19: 373-376.

Longinelli, A., and Paladino, A.P., 1980. Oxygen Isotope Composition of Water from Mammal Blood: First Results. *Mass Spectrometry in Biomedical and Environmental Research,* 1: 135-139.

Luz B, Kolodny Y, Horowitz M., 1984. Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. *Geochimica Cosmochimica Acta.* 48: 385–390.

Luz, B., and Kolodny, Y., 1985. Oxygen Isotope Variations in Phosphate of Biogenic Apatites V. Mammal Teeth and Bones, Earth and Planetary Science Letters, 75: 29-36.

Luz, B., Cormie, A.B., and Schwarcz, H.P., 1990. Oxygen Isotope Variations in Phosphate of Deer Bone. *Geochimica et Cosmochimica Acta,* 54: 1723-1728.

Matthews, D. E., and Hayes, J. M. 1978. Isotope-ratio-monitoring gas chromatography-mass spectrometry. *Analytical Chemistry*, 50: 1465–1473.

McEwan, G.F., 1996. Archaeological investigations at Pikillacta, a Wari site in Peru. *Journal of field archaeology*, 23: 169-186.

Menzel, D., 1964. Style and time in the Middle Horizon. *Nawpa Pacha*, 2: 1-105.

Michel, V., Ildefonse, P. and Morin, G. 1995. Chemical and structural changes in Cervus elephas tooth enamels during fossilization (Lazaret cave): a combined IR and XRD Rietveld analysis. *Applied Geochemistry*, 10: 145-159.

Moseley, M.E., Nash, D.J., Williams, P.R., deFrance, S., Ana Miranda, A., Ruales, M., 2005. Burning down the brewery: Establishing and evacuating an ancient imperial colony at Cerro Baul, Peru. *Proceedings of the National Academy of Sciences*, 102: 17264-17271.

Novoa Bollota, P. 2002. Arqueologia de la Cuenca del rio Grande de Nasca: Cuadernos de invertigacion del Archivo Tello; no. 3. Museo de Arqueologia y Antropolgia de la Universidad Nacional Mayor de San Marcos, Lima, Peru.

Poage, M.A. and Chamberlain, C.P. 2001. Empirical Relationships between elevation and stable isotope composition of precipitation and surface waters: considerations for studies of paleoelevation change. *American Journal of Science,* 301: 1-15.

Poage, M.A. and Chamberlain, C.P. 2006. Perspectives Geochemistry: Rising Mountain Ranges. *Science*, 311: 478-479.

Proulx, D., 1994. Stylistic Variation in Proliferous Nasca Pottery. *Andean Past*, 4: 91-107.

Quade J, Cerling TE, Barry JC, Morgan ME, Pilbeam DR, Chivas AR, Lee-Thorp JA, Merwe NJ van der., 1992. A 16-Ma record of paleodiet using carbon and oxygen isotopes in fossil teeth from Pakistan. Chemical Geology, 94: 183-192

Rey, C., Renugopalakrishnan, V., Shimizu, M., Collins, B. and Glimcher, M. J. 1991. A resolution enhanced Fourier transform infrared spectroscopic study of the environment of the CO_3 ion in the mineral phase of enamel during its formation and maturation. *Calcified Tissue International* 49, 259–268.

Rowe, J.H., 1963., Urban Settlements in Ancient Peru. *Nawpa Pacha*, 1: 1-27.

Rowe, J.H. 1995. Behavior and Belief in Ancient Peruvian Mortuary Practice. In *Tombs for the Living: Andean Mortuary Practices*, edited by T.D. Dillehay, pp. 27-41. Dumbarton Oaks Research Library and Collection, Washington, DC.

Schaedel, R.P., 1966. Incipient Urbanization and Secularization in Tiahuanacoid Peru, *American Antiquity*, 31: 338-344.

Schreiber, K.J., 1987. From State to Empire: The Expansion of Wari outside the Ayucucho Basin, in Jonathan Haas, Shelia Pozorski, and Thomas Pozorski, eds, *The Origins and Development of the Andean State, Cambridge*: Cambridge University Press, 91-96.

Schreiber, K.J., 1992. *Wari Imperialism in Middle Horizon Peru*. University of Michigan, Ann Arbor.

Schreiber, K.J., 1999. Regional approaches to the study of prehistoric Empires: examples from Ayacucho and Nasca. In: Billman, B.R. Feinman, G.M., (Eds.),

Settlement Pattern Studies in the Americas: Fifty Years since Viru, Smithsonian Institution Press, Washington, D.C.: 160-171.

Schreiber, K.J., Rojas, L.J., 1995. The Puqios of Nasca. *Latin American Antiquity*, 6: 229-254.

Schreiber, K.J. 2001. The Wari Empire of Middle Horizon Peru: The Epistemological Challenge of Documenting an Empire without Documentary Evidenc. In Empires: Perspectives from Archaeology and History, edited by S.E. Alcock, T.N. D'Altroy, K.D. Morrison, and C.M. Sinopoli, pp. 70-92. Cambridge University Press, New York.

Schreiber, K.J., Rojas, L. J., 2003. *Irrigation and Society in the Peruvian Desert: the Puquios of Nasca*. Lexington Books, Lanham, Maryland.

Shemesh, A. 1990. Crystallinity and diagenesis of sedimentary apatites. *Geochimica et Cosmochimica Acta*, 54: 2433-2438.

Silverman, H., 1993. *Cahuachi in the ancient Nasca world*. University of Iowa Press, Iowa City.

Silverman, H., Proulx, D., 2002. *The Nasca*. *The Peoples of America.* Blackwell Publishers, Oxford.

Smith, M.E., and Montiel, L., 2001. The Archaeological Study of Empires and Imperialism in Pre-Hispanic Central Mexico. *Journal of Anthropological Archaeology*, 20: 245-284.

Sponheimer, M., and Lee-Thorp, J.A. 1999. Alteration of Enamel Carbonate Environments during Fossilization. *Journal of Archaeologicl Science*, 26: 143-150.

Straight, W.H., Barrick, R.E., Eberth, D.A. 2006. Reflections of surface water, seasonality and climate in stable oxygen isotopes from tyrannosaurid tooth enamel. *Palaeogeography, Palaeoclimatology, Palaeocology*, 206: 239-256.

Stuart-Williams, H.L., Schwarcz, H.P., White, C.D. and Spence, M.W. 1996. The isotopic composition of human bone from Teotihuacan and Oaxaca, Mexico. *Paleogeography, Palaeoclimatology, Palaeoecology*, 126: 1-14.

Stuart-Williams, H.L., Schwarcz, H.P., 1997. Oxygen Isotope Determination of Climatic Variation using Phosphate from Beaver Bone, Tooth Enamel and Dentine. *Geochimica et Cosmochimica Acta,*. 61: 2539-2550.

Termine, J. D. & Posner, A. S. (1966). Infrared analysis or rat bone: age dependency of amorphous and crystalline mineral fractions. *Science* 113, 1523–1525.

Valdez, L.M. 1994. Cahuachi: New Evidence for an Early Nasca Ceremonial Role. *Current Anthropology*, 35: 675-679.

Vaughn, K.J., 2000. Moving beyond iconography: Neutron activation analysis of ceramics from Marcaya, Peru, an early Nasca domestic site. *Journal of Field Archaeology*, 27: 75-90.

Vaughn, K.J., 2005. Crafts and the Materialization of Chiefly Power in Nasca. Archeological Papers of the American Anthropological Association, 14 Arlington, VA: American Anthropological Association.

Weiner, S. and Bar-Yosef, O. 1990. State of Preservation of bone from prehistoric sites in the Near East: A survey. *Journal of Archaeological Science*, 17: 187-196.

White,C.D. and Spence, M.W., 1998. Oxygen Isotopes and the Identification of Geographical Origins: The Valley of Oaxaca versus the Valley of Mexico. *Journal of Archaeological Science,* 25: 643-655.

Williams, P.R. 2001. Cerro Baul: A Wari center on the Tiwanaku frontier. *Latin American antiquity*, 12: 67-83.

Wright, L.E. and Schwarcz, H.P. 1996. Infrared and isotopic evidence for diagenesis of bone apatite at Dos Pilas, Guatemala: paleodietary implications. *Journal of Archaeological Science*, 23: 933-944.