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THE EFFECT OF ENVIRONMENTAL CHANGE AND ECONOMIC POWER ON THE DIET OF TARASCAN ELITES

By

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ABSTRACT

THE EFFECT OF ENVIRONMENTAL CHANGE AND ECONOMIC POWER ON THE DIET OF TARASCAN ELITES

By

Laura Cahue

The Tarascan state emerged in the Lake Pátzcuaro basin (LPB) during the Postclassic period (A.D. 900 - A.D. 1520), when the water level of Lake Pátzcuaro was fluctuating. As these environmental changes were taking place and the food resources shifted, the population in the basin was undergoing rapid growth, reaching an estimated 80,000 by the time the Spaniards arrived in A.D. 1520 (Pollard, 1982; Pollard, 1993). By comparing population size and shifting food resources in the LPB, Gorenstein and Pollard (1983) showed that by the Late Postclassic (A.D. 1400 to A.D.1520), the basin was unable to produce enough maize to feed this population. How could the Tarascan state, the second largest in Mesoamerica, and one that dominated western Mexico at the time of European contact, emerge under such dietary constraints?

Ethnohistoric documents indicate that the Tarascan state was not an economically viable unit, and that it existed, and even thrived, only through the establishment of differential mechanisms of economic exchange (Pollard, 1982; Pollard, 1993). Non-elites obtained goods (including maize and beans) through the intensification of local and regional markets or subsistence activities, while the elites obtained most of their goods by outright ownership of local production or by tribute secured through militarism (Pollard, 1993). This study hypothesized that this differential adaptation of elites and

non-elites (which excluded agricultural intensification and hydraulic works) served to buffer the elite population in the LPB from dietary change as the Tarascan state emerged.

To test this hypothesis the diets of Pre-Tarascan and Tarascan elites were compared. Stable carbon and nitrogen isotopes ($\delta^{13}C$ and $\delta^{15}N$ values respectively) of bone collagen were used to assess temporal and regional variation in diet.

The results show that the diet of elites in the Lake Pátzcuaro Basin did not change over time. Among Tarascan administrative centers, elites at those administrative centers with a higher rank showed diets that were higher in relative proportions of maize than those of lower rank. The diet of elites at the capital city of Tzintzuntzan was significantly different from that of elites elsewhere. Elites in the Sayula Basin had diets closely resembling the diet of Tarascan elites from Tzintzuntzan, supporting the ethnohistoric and archaeological evidence for the presence of Tarascan administrators sent from Tzintzuntzan. Differences between males and females were not systematically examined due to inadequate samples, but a preliminary comparison of the data does not show a difference in diet between the two groups.

This dissertation is the first bioarchaeological study of palaeodiet in the Lake Pátzcuaro Basin, and it is the first step of a long term research agenda designed to understand human adaptation strategies to highland lake environments in west Mexico. Future research will aim to improve overall sample size, improve the female to male ratio in the samples, and to improve the regional distribution of samples.

To my mother, Ernestina J. Manrique de Cahue; my late grandmother Luz Alvarez de Manrique, and my friend Jane E. (Douglas) Kwilecki. At various points in my life, these women forced me to be strong when I felt afraid, loved me when I could not love myself, and trusted me when I did not know what I was doing.

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"Nothing defines humans better than their willingness to do irrational things in the pursuit of phenomenally unlikely payoffs."
-- Scott Adams --

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‰	per mil
$\delta^{13}C$	Stable isotope ratio of $^{13}C/^{12}C$ relative to a standard
$\delta^{15}N$	Stable isotope ratio of $^{15}N/^{14}N$ relative to a standard
A.D.	Anno Domini
AMA	Amacueca sample from the site of Atoyac
B.C.	Before Christ
M	Male
F	Female
SAY	Sayula sample from the site of Atoyac
TOC	Tócuaro
TZIN	Tzintzuntzan
TZIN-Os	Tzintzuntzan ossuary

Chapter 1

INTRODUCTION AND THEORETICAL BACKGROUND

This study examines the effects of environmental change and sociopolitical power on the diet of elites in the Tarascan state. The Tarascan state emerged during the Postclassic (A.D. 900 – A.D. 1522) in the Lake Pátzcuaro Basin (Figure 1); a time when lake level fluctuations resulted in shifts in the availability of food resources. A comparison of food availability, population estimates and consumption needs indicate that by the Late Postclassic (A.D. 1350 – A.D. 1522), the basin was unable to produce enough food to feed its population (Pollard, 1993). How did the Tarascan Empire, the second largest in Mesoamerica, and one that dominated western Mexico at the time of European contact, develop under these constraints?

This dissertation proposes that an emergent, socially stratified elite class in the Lake Pátzcuaro basin used its sociopolitical and economic power to obtain maize from outside the basin, and protected themselves against the effects of dietary change and the potential stress of calorie-energy malnutrition. This study measures dietary change and uses it as an indicator of the ability of elites to use their economic and political power to cope with fluctuations in food supplies.

Food, Power and Diet in Anthropology

The variety and range of human dietary patterns stand as testimony to the power of human societies to use culture to overcome environmental and social constraints on food supplies. Humans adapt to low energy or caloric intakes by conserving energy through a reduction in body weight, reduced activity levels, and lowering of metabolic

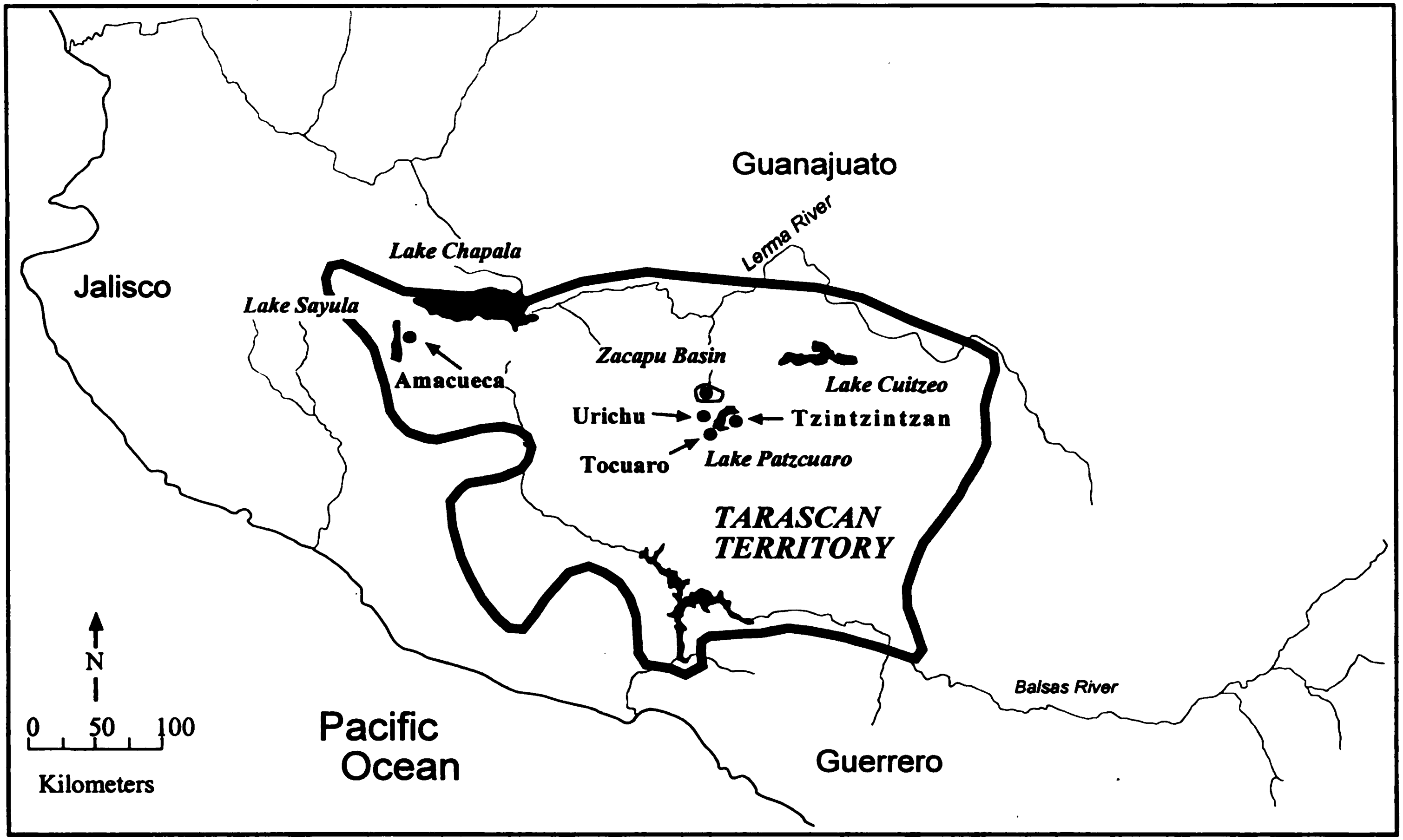

Figure 1. Map of the territory of the Tarascan State showing the location of the sites included in this study (modified from Pollard, 1993).

rates (Waterlow, 1990). When food surpluses are available and their future availability is uncertain, food can be consumed and stored in the body as excess fat, for example (Garine and Harrison, 1988; Little et al., 1990).

As effective as biology is in averting the consequences of food insufficiency, culture and technology play equally important roles (Douglas, 1975). Freezing, drying, canning and chilling technologies prevent the spoilage and contamination of foods, and help alleviate the effects of fluctuating food supplies. Once food is preserved, it can be stored for future use during periods of shortage. Raised fields, irrigation canals, sprinkler systems, fertilizers, and more recently, genetic manipulation, are all examples of technologies developed for increasing food production. When food supplies are uncertain, many human societies cope by altering their behavior related to food distribution and consumption. During the dry season, the Ngisonyoka Turkana adults will undergo voluntary fasting for days in order to ensure that children are well fed (Little et at., 1990).

Biological and technological coping strategies are important determinants of diet, but studies of human adaptation that ignore the social, political and economic context in which it takes place can be misleading in their findings (de Garine and Harrison, 1988). Furthermore, such studies fail to consider the social relations of power that are involved in food production and distribution, and consequently, their effect on human adaptation (Caplan, 1997). Anthropological studies with a focus on food as a source of power and prestige (Goody, 1982; Mintz, 1996) have shown that from prehistoric times to the present, food has played a central role in the development of socially complex and stratified societies. Due to the importance of food for survival and its social, political and economic role, changes in dietary patterns throughout the course of human evolution are critical to the study of human adaptation (Schoeninger and Moore, 1992).

Archaeology and bioarchaeology have an extraordinary capacity for evaluating human dietary patterns over large units of space and time (Saitta, 1998), and over the last twenty years, dietary reconstruction has become an important part of archaeological investigations. Knowledge of dietary intakes has helped in the evaluation of the nutritive effects of increased consumption of maize in the Nashville Basin (Buikstra et al., 1988) and the relationship between social complexity and agricultural intensification in the Ohio valley (Schurr and Schoeninger, 1995). Also examined has been the restricted access to foods to members of different social groups (sex, age, class, occupation religious status, etc.) in socially complex societies (Huelsbeck, 1988; White and Schwarcz, 1989).

Differential access to food will have an effect on the individual's nutritional status and ability to meet dietary needs, compromising his or her capacity to cope with infectious diseases, and ultimately affecting health (Larsen, 1997). Undoubtedly, this relationship is equally true for contemporary and ancient human populations, and it is examined through direct observation of human behavior or the study of human skeletal remains. The study of health in prehistory using human skeletal remains is the best means available for identifying patterns of differential access to resources (for example, food) between and within human groups (Saitta, 1998).

As long as the analytical focus is on issues that are amenable to archaeological investigation, archaeology can provide a long-term perspective on the political dimension of food, diet and health (Dietler, 1996; Saitta, 1998). An archaeological investigation of the role of food in the articulation and manipulation of status and power can move our understanding of ancient societies beyond the traditional studies of *what people ate* (Dietler, 1996; Hayden, 1996). While human diets must provide adequate nutrition for a population to survive, what people eat is more often a function of what they are *allowed* to eat, or what they are *required* to eat to ensure that the economic and political priorities of ruling classes and corporate elites are met (Harris and Ross, 1987).

This study uses a political economic approach to bioarchaeology because of its ability to examine the social and power relationships that constrain individual strategies to gain access to resources, including food (Goodman and Leatherman, 1999). The dissertation largely follows the theoretical framework outlined by the work of those anthropologists who convened for the Wenner-Gren International Symposium no. 115, "Political economic Perspectives in Biological Anthropology: Building a Biocultural Synthesis," held in Cabo San Lucas, Baja California Sur, Mexico in November of 1992 (Goodman and Leatherman, 1998a).

Political Economy in Bioarchaeology

Bioarchaeology, primarily concerned with how skeletal and dental tissues from archaeological contexts reveal life histories of individuals and groups, has its theoretical roots in the theoretical developments of its parent discipline, archaeology (Larsen, 1997). Early studies of skeletal remains focused on descriptions of skeletal morphology and pathologies. These studies, diagnostic in nature, were mostly concerned with documenting case studies of individual diseases (Ortner and Putschar, 1981). Until the 1970s, when larger skeletal collections became available for study, patterns in disease prevalence and morphology were not investigated (Larsen, 1997). These large-scale projects were conducted at a time when the discipline of anthropology in the United States was driven by cultural-ecological approaches to the way people adapted to changing environments (Little, 1995; Thomas, 1998). The concept of adaptation has considerable power as a theoretical tool to explain spatial and temporal variation in human biology and behavior. In spite of its extraordinary capacity for evaluating evolutionary change, it is not the only explanatory paradigm (Gould and Lewontin, 1979). Also problematic is the continued disagreement among evolutionary biologists and anthropologists over what constitutes the unit of adaptation (i.e., is it individuals, families, societies, populations, or ecosystems?) (Little, 1995). Its limitations notwithstanding, the concept of adaptation played a central role in the development of cultural ecology. This ecological perspective became a unifying force for anthropologists, as they sought to understand humans in their biological and cultural contexts (Baker, 1996). Studies with an ecological perspective examined the way in which humans manipulated their cultural and biological worlds to extract resources from their environments. The studies were, without a doubt, materialist and ecological, but their biocultural approach linked them to larger theoretical issues (Goodman and Leatherman, 1998). While ecological perspectives can evaluate how well people respond to adverse conditions, and what people do when their primary response systems are disrupted, they fail to examine why those adverse conditions exist, what are the processes in which they originate, and what dynamics keep them in place (Thomas, 1998).

In reaction to the cultural ecology of the 1960s, evolutionary biologists and sociocultural anthropologists addressed several important theoretical concerns. Evolutionary biologists criticized ecological approaches for their underlying assumption that adaptation was purposeful and progressive (Gould and Lewontin, 1979), suggesting instead, that evolution was the random product of historical contingencies (Gould, 1991). Within sociocultural anthropology the use of cultural ecology and modernization theory as theoretical frameworks were also under scrutiny. While cultural ecology was criticized because of its functionalist undertones and its assumption that human societies were closed, homeostatic and self-regulating systems (Ortner, 1984; Wolf, 1982), modernization theory was seen as progressive evolutionism (Goodman and Leatherman, 1998; Ortner, 1984). Thus, throughout the 1970s anthropologically informed political economic theories emerged in ersponse to approaches that failed to consider the centrality of human agents in social systems (Giddens, 1987).

Anthropological political economy is concerned with how micro- and macro-level systems and histories intersect to create the social context in which human action takes place. This approach is concerned with the social relations and institutions that control fundamental resources (including labor), and it views this control as an expression of power (Goodman and Leatherman, 1998; Roseberry, 1988). Power relations are formed within specific social fields (Roseberry, 1998). These social fields of power are web-like relationships that structure the appropriateness, availability and permissibility of responses to environmental (socio-political, economic or biological) change. The content of the relationships that form social fields is *"power: over who owns what, who works where, for how long, and with what return"* (Roseberry, 1998). Political economic perspectives consider the context and the individual's position within these social webs as factors that influence social action, providing an explanatory paradigm for human bio-behavioral variation (Roseberry, 1998).

The problem of food acquisition and consumption, and the ability to cope with it, are constrained by the availability of environmental and social resources (Goodman and Leatherman, 1998). A political economic perspective is particularly useful to biological anthropologists because it directs our attention to these problems. Themes that emerge from political economic bioarchaeology include the macro-level systems of natural and social resources, and the historical contingency of the constant reshaping of those environments to which humans must adapt (Goodman and Leatherman, 1998; Roseberry, 1989).

The emergence of state societies is associated with the emergence of social, political, and economic differences within and between social groups. Regional differential access to power is the organizing force around which individual actors must negotiate their social positions. A political economic bioarchaeology is uniquely suited to examine the biological consequences of this differential access to power (Martin, 1998; Saitta, 1998).

The difficulty of inferring social inequality from archaeological evidence, however, has prompted archaeologists to gather evidence from a variety of disciplines. Multidisciplinary approaches to studies of ancient societies have the ability to address the complexity of interactions between various lines of evidence, and facilitate the examination of food production and distribution, and its role in the acquisition of status and power. This dissertation uses a multidisciplinary approach, drawing information primarily from human skeletal biology, ethnohistory, archaeology, and biogeochemistry.

Chapter Two reviews the literature on palaeodiet reconstruction techniques available to archaeologists and physical anthropologists to reconstruct the diets of ancient populations. The focus of the chapter is on the method of stable isotope mass spectrometry. It makes the argument that this method is best suited for fragmented and incomplete collections such as those found throughout west Mexico. The chapter highlights the ability of the method to provide dietary information at the individual level of analysis in studies of food and power.

Chapter Three is a review of Tarascan archaeology and ethnohistory. This chapter focuses on recent developments in our understanding of Tarascan prehistory and the cultural developments that lead to the formation of the Tarascan State. The primary purpose of the chapter is to provide a context for the archeological problem under investigation. To this end, the chapter outlines the various lines of evidence, drawn from a number of disciplines, used to organize what we know about the Tarascans and conceptualize what we still wish to learn.

Chapter Four has four sections: expectations, materials, hypotheses, and methods. The expectations section presents a brief discussion of the arguments used to construct each hypothesis tested in the study. The materials section presents an overview of the skeletal collections used in the study. A description of those collections included in this study includes: mortuary context, preservation, and completeness. Age and sex determinations are also discussed. The hypothesis section presents formal null and alternative hypothetical statements and the criteria used to reject or accept the null hypotheses.

The methods section includes complete descriptions of sampling criteria, and laboratory protocols for collagen extraction, assessment of indigeneity and mass spectrometric measurements. Included in this section is a discussion of the statistical methods used to analyze the data. This section makes an argument for the suitability of non-parametric statistical techniques to the samples in the study.

Chapter Five presents aggregated and disaggregated data, along with the results of the statistical tests.

Chapter Six discusses the results and offers plausible explanations for the patterns of variation and distribution displayed by the data. The chapter concludes the dissertation with a discussion of the limitations and strengths of the study. It also proposes future research areas to address the limitations of the study, and discusses its contribution to anthropology in general and to west Mexican archaeology, Mesoamerican studies, and Mexican physical anthropology in particular.

Chapter 2

PALAEODIETARY RECONSTRUCTION

Various methods and techniques from a wide range of disciplines are available to archaeologists for the reconstruction of ancient diets. These diverse methods provide information on a large or small scale; and the units of analysis range in scale from groups such as populations and species to individuals (Schoeninger and Moore, 1992; Schwarcz and Schoeninger, 1991).

Optimal foraging models, site catchment analysis, and the analysis of floral (Hastorf and Popper, 1988), faunal (Jackson and Scott, 1995), ceramic and stone tool (Blitz, 1993; Jones, 1996) remains provide information about groups. These analytical approaches have proven invaluable to archaeologists because they help identify the food items in the diet, although they are unsuitable for the assessment of the relative quantitative importance of individual food items in the diet (Schwarcz and Schoeninger, 1991). Foods incorporated into the archaeological record, whether deliberately or unintentionally, do not often directly reflect the systematic use of foods. Middens, for example, are imperfect samples of ancient human behavior because plant and animal remains undergo different taphonomic processes that result in their biased representation in the archaeological record (Schoeninger and Moore, 1992). In spite of these problems, assemblages of plant remains have been useful in elucidating patterns of change in plant use (Johannsen, 1988). Cut marks on animal bones recovered from middens have provided information on butchering and processing practices (Marshall, 1986), as well as the preferential utilization of specific parts of the animal with regard to nutritional consequences (Speth, 1983).

Tools tell us more about the processing of foods than they do about the consumption of foods. For example, food residues on the internal surfaces of cooking vessels may help in the identification of the foods that were processed, but cannot help determine whether they were consumed. Furthermore, the analysis of many vessels would be necessary to recognize the dietary importance of different foods, since individual ceramic sherds represent a very small sample of behavior (Schoeninger and Moore, 1992).

Dietary analysis aims to identify the foods and their relative proportions in the diet. Qualitative reconstructions of diet reach their greatest power for understanding prehistoric subsistence systems when combined with quantitative methods that provide dietary information for individuals rather than groups (Schoeninger and Moore, 1992; Schwarcz and Schoeninger, 1991).

Analytical methods that provide information about individuals include studies of stomach content, fecal remains, and human skeletal remains. Skeletal remains studied by physical anthropologists can provide information about diet and its effect on health; these studies are useful in determining the variety of foods that were available for consumption to people from different socio-economic strata, and the differential effects that their consumption had on the health of individuals. The analysis of microwear patterns on teeth, palaeopathology, and histomorphology of bone tissue gleans dietary information from the human skeleton (Larsen, 1997). Microwear analysis of teeth helps identify foods processed in the mouth over several months preceding death. For example, the disappearance of the high polish on teeth, left by vegetable fibers, is associated with the introduction of maize agriculture (Rose and Harmon, 1986).

Physical anthropologists have detailed increases in the frequency of carious lesions in prehistoric hunter-gatherers and maize agriculturalists. Overall, there is a clear tendency for prehistoric maize agriculturalists to have higher frequencies of carious lesions than do prehistoric foragers (Larsen, et al., 1991). Among maize agriculturalists, however, the association between increased reliance on maize and carious lesions is variable. Furthermore, it appears that relatively small changes in diet and food processing techniques can result in large differences in the prevalence of carious lesions (Larsen, et al., 1991).

Palaeopathology, developmental defects in bone and enamel, and micromorphology of bone cross sections help determine the nutritional adequacy of diet (Martin, et al., 1985). For example, White and Armelagos (1997) examined the micromorphology of femoral transverse sections of Nubian mummies to evaluate the relationship between osteopaenia and diet. They found that osteoporotic individuals had elevated nitrogen isotope ratios, suggesting water stress in an arid environment, or protein stress.

The combination of these methods and techniques plays a crucial role in the determination of what individuals ate, and the effect it had on their health. Studies of the actual foods consumed (and the relative amounts in which they were eaten), however, were not possible until the mid-1970s when methods for the chemical analysis of bone were first applied to anthropological problems. These new technological developments made it possible for anthropologists to measure diets and evaluate the relationship between diet, health and social status.

The application of stable isotope analysis to the reconstruction of prehistoric diets is based on the premise that the isotopic composition of an animal's tissues is similar to, or deviates by a consistent amount from, that of its diet (Ambrose, 1993; Chisholm, 1989; Katzenberg, 1997; Schwarcz and Schoeninger, 1991; van der Merwe, 1982; Vogel and van der Merwe, 1977). This assumption has been validated in controlled feeding experiment with laboratory animals (DeNiro and Epstein 1978). Today, the variation in the carbon and nitrogen stable isotope ratios of bone collagen aids in the reconstruction of prehistoric human diets and a variety of anthropological problems (Schwarcz and Schoeninger, 1991; Katzenberg, 1992). Various studies have provided information on the type of foods consumed, the proportions of different food items in the diet, and variation in diet through time and space (Schwarcz, et al. 1985; Schwarcz, 1991).

Principles of Stable Isotope Analysis

Isotopes are atoms of chemical elements with the same number of protons but different number of neutrons, resulting in different atomic masses. The isotopes of an element have the same chemical properties, but differ in their rates of reaction, with the lighter isotopes generally reacting more readily than the heavier isotope (Ambrose, 1993; Katzenberg, 1992; Schwarcz and Schoeninger, 1991). Isotopes that decay through time into another element are radioactive and can be used for radiometric dating; stable isotopes do not transmute into other elements. The stable isotopes of carbon, nitrogen and oxygen are the most utilized in palaeoclimatic and palaeodietary studies. Stable carbon and nitrogen isotope analysis involves the measurement of the ratio between two isotopes ($^{13}C/^{12}C$ and $^{15}N/^{14}N$, for example). Because the concentrations of ^{13}C and ^{15}N are very low in the biosphere, the ratios $^{13}C/^{12}C$ and $^{15}N/^{14}N$ cannot be measured directly. Rather, the ratios are expressed as:

$$\delta^{13}C \text{ or } \delta^{15}N = [(R_{sample}/R_{standard}) - 1] \times 1000$$

where R is $^{13}C/^{12}C$ or $^{15}N/^{14}N$ for $\delta^{13}C$ or $\delta^{15}N$, respectively. The internationally recognized standard for carbon is the marine carbonate PeeDee Belemnite (PDB) and for nitrogen the international standard is atmospheric N_{air}.

Carbon

Smith and Epstein (1971) documented a difference in $\delta^{13}C$ values between C_3 plants (those utilizing the Calvin-Benson photosynthetic pathway) and C_4 plants (those that follow the Hatch-Slack photosynthetic pathway). Maize belongs to the C_4 plant group, which has $\delta^{13}C$ values in the range of -12.5‰ to -13.1‰ for modern maize (Smith and Epstein, 1971; Boutton, 1991; Tieszen 1991). The average $\delta^{13}C$ value for modern C_3 plants is -26.5‰ (Smith and Epstein, 1971; Boutton, 1991; Tieszen 1991). Plants derive their carbon from atmospheric CO_2, and any changes in the isotopic composition of atmospheric CO_2 will affect the isotopic composition of plants. The burning of fossil fuels (coal, petroleum, and natural gas) has resulted in a decrease $\delta^{13}C$ value of atmospheric CO_2 of approximately 1.4‰ (van der Merwe, 1989).

Fossil fuels are strongly depleted in ^{13}C because they are, primarily, the products of decomposition of C_3 plants. The $\delta^{13}C$ values of coal range between –20.0 and –13.0‰; petroleum ranges between –27.0 and –30.0‰. The range of $\delta^{13}C$ values of natural gas depends on the molecular composition and origin of the hydrocarbon gases. Natural gas is mostly formed of methane (CH_4) (Faure, 1998). The $\delta^{13}C$ values of methane formed through anaerobic decomposition of cellulose range to about –80.0‰; and methane formed by the breakdown of larger hydrocarbon molecules ranges in $\delta^{13}C$ value from –25.0 to –50.0‰ (Faure, 1998). Ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}), also found in natural gas, are less depleted in ^{13}C than methane (Faure, 1998).

Because of the downward shift in $\delta^{13}C$ value of atmospheric CO_2, prehistoric plants are more positive than modern plants (Keeling et al., 1979). Measurements of prehistoric maize show an average $\delta^{13}C$ of -9.0‰ (Schwarcz, 1991).

Consumers will reflect the isotope value of their diet. Carbon isotopic values of the diet are recorded in the tissues of terrestrial and marine herbivores, with a secondary metabolic fractionation that depends on the tissue examined. Feeding experiments on small animals show diet-tissue differences between 1.0 and 3.0‰; and for larger animals between 3.0 and 5.0‰ (Schoeninger and Moore, 1992). Although there is considerable disagreement in the magnitude of the diet-tissue differences measured, the estimate for the difference in the $\delta^{13}C$ value of bone collagen and diet is generally accepted to be approximately 3 - 5‰ (Schwarcz and Schoeninger, 1991). That means. for example, that an animal consuming a diet consisting of 100% C3 plants, with an average $\delta^{13}C$ value of –26‰, will have a $\delta^{13}C$ value of bone collagen approximately –20‰.

Nitrogen

Some plants incorporate nitrogen from soil in the form of nitrate or ammonium, while others do so directly from the atmosphere via nitrogen fixing symbionts

(Schoeninger and Moore, 1992). Legumes retain endosymbionts and have $\delta^{15}N$ values similar to that of atmospheric N_2 (0‰) (Schwarcz and Schoeninger, 1991). Most non-legumes rely on soil ammonium or nitrate that typically have values greater than that of atmospheric N_2 (Hoefs, 1987). Thus, legumes have $\delta^{15}N$ values that are typically lower than non-legumes (Schwarcz and Schoeninger, 1991).

As in the case of carbon, the magnitude of difference between the $\delta^{15}N$ of bone collagen and diet is somewhat uncertain. Animal feeding experiments indicate that the $\delta^{15}N$ of bone collagen is approximately 3‰ higher than that of diet (DeNiro and Epstein, 1981; Hare et al., 1991). Researchers have reported $\delta^{15}N$ values of bone collagen that are higher than expected, however, indicating that $\delta^{15}N$ values may be affected by factors other than diet (Schoeninger and Moore, 1992). Water stress, protein restriction, and high protein diets, for example, have all been implicated in elevated $\delta^{15}N$ values of bone collagen (Ambrose and DeNiro, 1986; Heaton et al., 1986; Sealy et al., 1987).

In addition to the diet-tissue spacing in $\delta^{15}N$, an upward shift of 3‰ in $\delta^{15}N$ values also occurs with each trophic level (DeNiro and Epstein, 1981). Trophic level shifts, therefore, must be accounted for when the relative contribution of different dietary sources to a consumer are estimated (Schwarcz, 1991; Little and Schoeninger, 1995).

Isotopic routing effects on bone collagen and apatite carbonate

Diet-tissue fractionation factors are not constant, and can vary as a function of proportion and quality of protein in the diet (Ambrose, 1993; Schwarcz and Schoeninger, 1991; Parkington, 1991). Some dietary macronutrients may be preferentially "routed" into particular tissue without homogenizing with the rest of the body's atoms (carbon and nitrogen atoms, for example) (Schwarcz, 1991).

Controlled-diet studies on animals indicate that carbon from carbohydrates and lipids is preferentially routed to bone apatite carbonate, while that from protein seems to be incorporated into bone collagen (Ambrose, 1993; Ambrose and Norr, 1993; Krueger and Sullivan, 1984; Lee-Thorpe, et al., 1991; Parkington, 1991). This suggests that $\delta^{13}C$ from bone apatite carbonate measures the isotopic signature of the total diet, while that of collagen measures the isotopic signature of the dietary protein sources (Ambrose, 1993; Schwarcz, 1991). A comparison of the isotopic composition of collagen to that of bone apatite carbonate can detect this type of routing for carbon (Lee-Thorp and van der Merwe, 1988).

In spite of the convincing evidence for routing of amino acids to protein synthesis, the assumption that the body utilizes dietary protein preferentially during collagen synthesis may be untenable under conditions of low protein intake (Ambrose and Norr, 1993; Tieszen and Fagre, 1993). Schwarcz (in press) has shown that the results of these studies reflect an inhibition of endogenous synthesis of amino acids when the amino acid level in the extra-cellular fluid is already at, or above, a critical point. This inhibition is more likely present in animals (or humans) with adequate amounts of protein in their diets. The protein is broken down into its respective amino acids in the liver. These amino acids are made available to the cell for protein synthesis (Schwarcz, in press).

Data from isotopic palaeodiet studies of maize consumers seem to confirm this point. In a study of maize-consuming prehistoric populations in Eastern North America, Buikstra and colleagues (1988) found high $\delta^{13}C$ bone collagen values, indicating that most of the carbon in the collagen came from maize. To produce these high $\delta^{13}C$ values, collagen must have incorporated carbon from carbohydrates because maize is relatively low in protein and lacks sufficient levels of some amino acids (Ambrose, 1993). At Maya sites from Belize, some individuals have $\delta^{13}C$ bone collagen values > -10‰. If a linear mixing model (all atoms mix together to form a common pool from which the body can then draw necessary atoms for tissue synthesis) is assumed, these values represent a diet with up to 70% maize (Schwarcz, 1991). About 80% of carbon atoms come from dietary protein and not from carbohydrates (Ambrose and Norr, 1993). Since some of the dietary protein in the diet of Belize Maya was derived from the flesh of herbivores like peccaries and turkeys, the calculation of the percent C_4 (PC_4) based on a linear mixing model, would underestimate the proportion of maize in the diet. In contrast, a routing model would estimate that a collagen with a $\delta^{13}C$ = -10‰ represents a diet composed of over 100% maize (Schwarcz, in press). At Maya sites in Belize, the PC_4 (70%), based on a linear mixing model, is already close to the upper limit of nutritional acceptability (no values greater than 75% maize in the diet have been recorded). Therefore, for populations with a high dependence of maize, a routing model is unacceptable (Schwarcz, in press).

A large portion of the animals consumed by the Maya (for example dogs and turkeys) ate diets consisting of some C_4 foods (maize) (Cannon, et al., 1999). Mesoamerican populations undoubtedly consumed C_4-based meat and there is evidence that they also consumed some C_3-based meat, suggesting that a routing model may overestimate C_4 consumption levels (Schwarcz, in press).

Still, in diets with adequate levels of animal protein for collagen synthesis, carbon from carbohydrates and lipids are under-represented in collagen (Ambrose, 1993). Because endogenous amino acid synthesis is suppressed (inhibited) in the presence of relatively high concentrations of the respective amino acid in the extra-cellular fluid, we might expect a strong inhibition effect (routing) in populations which consumed high levels of animal protein (Schwarcz, in press). In contrast, populations with dietary protein generally in low supply or largely derived from plants would approach a linear mixing model because the carbon atoms of all foods (except lipids) would be randomly assigned to the synthesis of all tissues (Schwarcz, in press).

The biochemistry of collagen synthesis notwithstanding, the isotopic fractionation between apatite and total diet is somewhat variable (Ambrose, 1993); making it difficult to use $\delta^{13}C$ of apatite as an index of total dietary $\delta^{13}C$ values (Schwarcz, in press). Furthermore, biogenic $\delta^{13}C$ signals of archaeological bone, in particular apatite, may be altered by exchange of carbonate (CO_3^{-2}) with ground water or soil water after burial, or by dissolution and recrystallization of bone mineral. In spite of the susceptibility to diagenetic alteration of bone apatite, few researchers systematically evaluate the apatite composition prior to $\delta^{13}C$ studies (Wright and Schwarcz, 1996). Infrared and isotopic evidence at the Maya site of Dos Pilas in Guatemala were used to evaluate the diagenesis of bone apatite (Wright and Schwarcz, 1996). The results of this study show that even relatively recent bone may be diagenetically altered. Diagenetically altered bone can be treated with acetic acid to remove calcium carbonate from bone interstices, but the removal of carbonate contamination within the apatite mineral remains a serious problem (Koch et al., 1990; Sillen, 1986).

Where diagenetic alteration has not been a factor, the isotopic analysis of bone apatite has not been of significant use. In a study of five New England populations, Bourque and Krueger (1994) compared dietary reconstructions based on faunal remains and historical documents to those using carbon and nitrogen isotopes of collagen and carbon isotopes in bone apatite carbonate. The results show a high correlation between $\delta^{13}C$ values of collagen and apatite carbonate, indicating no gain in dietary information from the analysis of apatite (Katzenberg and Harrison, 1997).

The difficulties of detecting diagenetic changes in bone apatite and our limited knowledge of the role that biochemical processes play in protein synthesis make bone collagen the bone fraction of preference for stable isotope analysis. In light of these findings and the fact that the present study is concerned with relative amounts of maize (more, less, the same), the analysis in this dissertation will be limited to bone collagen.

Assessing the Reliability of Stable Isotopic Ratios in Bone Collagen

Archaeological bone may undergo complex post-mortem diagenetic changes that result in the chemical alteration of proteins and apatite carbonates (Ambrose, 1991; DeNiro, 1985; Schwarcz and Schoeninger, 1991). Diagenetic alteration of bone, that is, the sum of the physical, chemical and biological processes that occur in the postmortem environment, may result in the addition or removal of organic materials to bone (DeNiro, 1985; Hedges and Law, 1989).

The elemental and isotopic composition of collagen and apatite carbonate may be altered depending on how much exogenous organic material is added or removed; and on how different the C/N, $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios of the added or removed organic material are from those that characterize the indigenous material (DeNiro, 1985). Exogenous organic materials such as humic acids and fungi can be mechanically or chemically removed prior to isotopic analysis to protect the fidelity of the dietary signal. Diagenetic changes have been shown to alter the dietary signal in bone collagen, therefore, it is essential that diagentic changes be evaluated (DeNiro, 1985).

For collagen extracts, values of the ratio between carbon and nitrogen (C/N) between 2.7 and 3.6 are consistent with retention of the original isotopic value (DeNiro, 1985; Schoeninger and Moore, 1992). Even well preserved bone will have lost some of its collagen to heat and hydrolysis. Because of this, collagen yields are a good measure of the degree of preservation of this protein in bone (DeNiro and Weiner, 1988). Ambrose (1990) has demonstrated that samples that yield collagen weights of at least 2% or greater than those of dry bone weights have well preserved isotopic signatures.

The "Menu" and the "Meal": the Reconstruction of Diet

Given our understanding of the $\delta^{15}N$ and $\delta^{13}C$ values of dietary items, maize should differ from all other food sources based on $\delta^{13}C$ values. Legumes should have lower $\delta^{15}N$ values than other dietary items. Fish, deer, rabbit, turkey, duck are C_3 plant consumers and should have higher nitrogen isotope values than plants, and lower carbon isotope values than maize (even when a protion of the diet includes maize or other C_4 plants). Consequently, legumes, maize, and animal protein sources (fish or meat) should differ in their isotope values. Accurate knowledge of local isotopic composition of food items is necessary for precise dietary reconstructions (Ambrose, 1993; Schwarcz, 1991; Schwarcz and Schoeninger, 1991). A pilot study was conducted to determine isotopic values among food sources known to be important to the Tarascans. Food items included skeletal remains of fish (*Goodea luitpoldi*), rabbit (*Sylvilagus floridamus*), deer (*Odocoileus virginianus*), peccary (*Tayassu tajacu*), turkey (*Melagris gallopavo*), and dog (*Cannis familiaris*). All dietary items were recovered from the site of Urichu in the Lake Pátzcuaro Basin, and date to the Pre-Tarascan period (Early Postclassic ~ A.D. 900) (Pollard, 1995). Table 1 shows the $\delta^{13}C$ and $\delta^{15}N$ values for these dietary items. These values compare to those obtained for faunal remains from Southern Ontario by Katzenberg (1989) where dogs had $\delta^{15}N$ values of 9.6‰, possibly due to feeding on human diet leftovers; turkeys had $\delta^{15}N$ values of 6.9‰, and freshwater fish a value of 3.6‰ for a bottom feeder. Carnivorous (picivorous) fish in Southern Ontario have a higher average $\delta^{15}N$ value (8.8‰) than carnivorous fish from the Lake Pátzcuaro Basin (6.5‰). With the exception of an archaeologically recovered maize cob from Urichu (as yet unanalyzed) no plant dietary items are available for isotopic analysis.

Previous Applications of Stable Isotope Analysis

Stable isotope data have been applied to a diversity of anthropological questions. The introduction of agriculture in the New World was marked by the arrival of the C_4 plant maize (*Zea mays*). The intensification of maize cultivation and its increased use as a staple food item after its domestication in North America, have been subjects of intense anthropological investigation. The relationship of maize agriculture intensification and the development of chiefdoms have been of particular interest to archaeologists (Schurr and Schoeninger, 1995). Likewise, physical anthropologists have paid considerable attention to this relationship and its effect on the health of North

TABLE 1

Stable Carbon and Nitrogen Isotope values for Food Items in the Tarascan Diet

Pre-Tarascan species (A.D. 350 - 1100)	**Bone Collagen** $\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
FAUNA [A]		
Rabbit *(Sylvilagus floridamus)*	-19.7	2.6
Deer *(Odocoileus virginianus)*	-20.5	5.1
Fish *(Goodea luitpoldi)*	-12.9	6.5
Turkey *(Melagris gallopavo)*	-12.1	6.7
Peccary *(Tayassu tajacu)*	-12.5	8.0
Dog *(Cannis familiaris)*	-10.0	9.8
C_4 PLANTS		
Maize [B] *(Zea maize)*	-9.0	8.7
Amaranth [C] *(Amaranthus sp.)*	-12.5	11.1
C_3 PLANTS		
Beans [C] *(Phaseolus vulgaris)*	-26.0	0.0
Chenopodium [C] *(Chenopodium sp.)*	-26.0	7.4

[A] Measured from Archaeological Bone
[B] Schwarcz et al., 1985
[C] Schoeninger, 1995

American prehistoric populations (Buikstra and Milner, Bumsted, 1984; Cohen and Armelagos, 1984; Katzenberg, et al., 1985; Spielman, et al., 1990).

Isotopic analyses of Mesoamerican and South American populations show a highly variable pattern of maize consumption. Maize consumption in the Tehuancan Valley appears to occur far earlier than in other regions of North America, with a shift to maize by 4000 B.C. (DeNiro and Epstein, 1981). In lower Central America, Maize consumption in Panama between 3000 and 5000 B.C. is minimal; and in Costa Rica the adoption of maize is dated to ca. A.D. 300 – 1550 (Norr, 1991).

By far, the Lowland Maya region is the most extensive, isotopically studied region of Mesomerica (White and Schwarcz, 1993; White, et al., 1993, 1994; Wright and Schwarcz, 1996; Wright and White, 1996). Stable isotope studies in the region have changed the picture of Maya dietary ecology. Evidence from Lamanai and Pacbitun in Belize indicate that the Maya were less reliant on maize than were other Mesoamerican populations (White, et al., 1993) showing a nonlinear temporal change in the emphasis on maize (Wright and Schwarcz, 1989).

No stable isotopic studies of ancient diet have been conducted previously in the West Mexican region. In spite of recent ethnohistoric and archaeological research in West Mexico, bioarchaeological studies in the region are still few. Recent archaeological research in west Mexico has challenged culture-historical paradigms that link west Mexico to other regions, and has produced new data for the interpretation of the human ecology of highland lakes (Arnauld, 1996; Macias-Goytia and Vackimes Serret, 1990; Pollard, 1997; Valdez , et al., 1996). Unfortunately, bioarchaeological research in west Mexico has not followed the same trend. With few exceptions (Cahue, 1999; Urunuela, 1998), the analyses of skeletal material in the region are mostly focused on studies of patterns of mortuary treatment, cranial and dental alterations, population genetic histories, and taphonomy (Cahue and Pollard, 1999; Macias Goytia, 1989; Pereira, 1995, 2000; Pickering, et al. 1985). One reason for this pattern is that physical anthropologists working in the region are not directly interested in human adaptation and biocultural aspects of human health and behavior. Another reason may be that skeletal materials in the region are often incomplete and not well preserved, impeding the use of traditional methods of analysis of skeletal indicators of health. To fill these theoretical and analytical gaps in bioarchaeological research in west Mexico, a research program to understand human adaptation to highland lake environments is under development. The research program will have a strong biocultural focus and will address the interaction between food availability, infectious diseases, population size, sociopolitical complexity and economic power, and the effect this interaction has on the health of human populations in the region. This dissertation is the first contribution toward the development of this program. It uses carbon and nitrogen isotopes to examine regional and temporal variations in elite diets during the development of the Tarascan state in the Lake Pátzcuaro Basin.

To summarize, the diet of ancient populations is an important component of bioarchaeological research. A variety of analytical methods have been developed to understand subsistence strategies across time and space. These methods have expanded our knowledge about the types of foods produced, processed and consumed by ancient populations. Analytical methods for the study of skeletal remains (human and nonhuman) have produced a significant body of literature that elucidates the various ways in which dietary practices affect skeletal biology.

This dissertation is concerned with determining the relative amounts of maize actually consumed by elites in the Lake Pátzcuaro Basin and how diet was affected by environmental change and economic power. This study uses skeletal collections that are fragmentary and incomplete. Stable isotope analysis was selected for this study because of its ability to glean dietary information from collections consisting of skeletons that have undergone some diagenetic alteration, are fragmented and incomplete.

In the following chapter the archaeology, ethnohistory and Bioarchaeology of the Tarascan state are presented as background to the anthropological problem under investigation in this study.

Chapter 3

FOOD AVAILABILITY, POPULATION GROWTH AND THE DEVELOPMENT OF THE TARASCAN STATE

Two great civilizations emerged in Mesoamerica during the Postclassic (A. D. 900-1500). These two polities were the Aztecs, who settled in the Basin of Mexico, and the Tarascans who settled in the Lake Pátzcuaro Basin in the modern state of Michoacán, in west México (Figure 1). At the time of Spanish contact, the Tarascans held political and economic control of west Mexico, and although they maintained an active military frontier with the Aztecs, the Tarascans successfully resisted their conquest attempts. The Tarascans, known among the Aztecs for their military prowess, also impressed the Spaniards with their economic administration and strong political control over their territory (Gorenstein and Pollard, 1983).

The process of state expansion resulted in the incorporation of increasingly diverse communities. This diversity challenged the state's economic and political power. To ensure economic exploitation of populations and resources, and to secure the integrity of its frontiers, the state had to integrate these communities (Pollard, 1993). The sole purpose of ethnic integration was to serve the interests of the Lake Pátzcuaro Basin, in particular the elite at Tzintzuntzan. The state was divided into three ethnic zones: an ethnic heartland, an area of active ethnic assimilation, and a zone of ethnic segregation.

The first zone was the heartland (mostly the Lake Pátzcuaro Basin), where several cultural/linguistic groups lived before the formation of the Tarascan state, was transformed into a zone where Tarascan ethnicity characterized the cultural identity and Tarascan became the dominant language. Local leaders of administrative centers within this region were appointed by the Tarascan king, and dealt directly with the Tzintzuntzan elite administrators and were assumed to be loyal to the state (Pollard, 1993).

The second zone, active assimilation, was added to the state after 1440. Many of the resources used by elites in the Lake Pátzcuaro Basin to mark their status came from this zone. Because of this, elites became increasingly more dependent on this population, and its loyalty to the state was of great concern to Tzintzuntzan. Loyalty was ensured by a process of gradual ethnic assimilation; a process that required local populations to perceive benefits for themselves. The Tarascan state provided local leaders with prestige and power from direct association and identification with the state's social structure. In return for their loyalty, local leaders were elevated to local state administrators (*angámecha,* he who wears a lip plug), marking their position with the ceremonial insertion of a lip plug during the feast of *sicuíndiro* (RM, 1980). Local claims to resources and social status, were not legitimized.

The third zone was one of ethnic segregation, and it extended out to the frontiers of the state. In this area, loyalty to the Tarascan elite in Tzintzuntzan was ensured through the provision of military protection. Administrators in this zone were elites sent in from the state's geopolitical core; ambassadors of sorts, that articulated with the local population to secure resources and make sure the community remained loyal. A set of burials at the site of Atoyac, in the Sayula Basin, which included Tarascan burial goods (polychrome ceramics, bronze metal objects, obsidian lip plugs) seems to represent Tarascan administrators sent by the state.

Imports used for the elite came not only from within the Tarascan state, but also from beyond. Turquoise, for example, came from the northwest, marine shell from the

Pacific, and jade and jadeite from Oaxaca and the Motagua Valley in Honduras (Pollard, 1999). The channels of acquisition of these exotic precious items were less in number as the distance of their sources increased, making the use of the items more restricted (Pollard, 1993). These luxury goods served largely to maintain status differences between the elite and the rest of the population.

Within the Lake Pátzcuaro Basin in the heartland, the Tarascan state maintained administrative control of its economic networks by establishing administrative units. These administrative centers were directly under the control of the Tarascan capital, and governed by members of an administrative elite class, designated by the Tarascan king (Pollard, 1993). Gorenstein and Pollard (1983) used Thiessen polygons to locate the administrative units in the Lake Pátzcuaro Basin and rank them in a hierarchy of five levels.

As the administrative center for the state territory, Tzintzuntzan was the only Rank 1 center; and as the administrative center for the Basin, it was also designated as a Rank 2 center. Below Tzintzuntzan there were eight administrative centers with Rank 3. Rank 3 centers were those centers subject to Rank 2 settlements, and in administrative control of several settlements (Rank 4 and 5). The Rank 3 administrative centers were all equal in power and status within the state. Links between same-rank centers were minimal if existent at all, and decision-making power flowed directly from Tzintzuntzan (Gorenstein and Pollard, 1993).

Documentary evidence for the origin and expansion of the Tarascan state is primarily known from the *Relación de las ceremonias y ritos y población y gobernación de los indios de la provincia de Michoacán*. This document, recorded between 1538-

1541, was translated and transcribed by the Franciscan priest Fray Jerónimo de Alcalá (Warren, 1971). Several editions of the *Relación de Michoacán* (RM), as it is commonly known, have been published (1956, 1980), including translations into English and French (Pollard, 1993). Several other documents written within the Tarascan territory during the early colonial period supplement the RM. These include the *Relaciones Geográficas de Michoacán* (RG) of 1579–1580 (1958, 1985, 1987), and the *Visitas de Carvajal* of 1523-1524 among others. Also important are sixteenth-century dictionaries and grammars of the Tarascan language. These include a grammar written by Maturino Gilberti in 1558 and two dictionaries, one also by Gilberti in 1559 and another by Juan Baptista de Lagunas in 1574 (Warren, 1983).

In all likelihood, episodes of lake level fluctuation influenced the development of the Tarascan state. Lake level fluctuations directly affected the availability of irrigable land, which was very important in supporting maize production (Pollard, 1982, 1993). When the lake level was low, it exposed the most fertile land in the basin. The exposure of fertile land may have attracted distant populations to the basin, contributing to an increase in population density. Conversely, when the lake level was high, the availability of exposed lacustrine soils along the lakeshore was reduced, reducing the agrarian potential of the basin. A reduction in agrarian potential, in particular that for the cultivation of maize, at a time when the population was increasing rapidly, would have undoubtedly placed enormous pressure on local communities to compete for access to, and control of, available irrigable land.

Pollard (1982) calculated that the basin could only produce enough maize to support a population of 45,000, clearly not enough to feed the 80,000 people estimated to have lived in the Basin by the end of the Late Postclassic (A.D. 1350-1522). A comparison of available resources, population size and consumption needs suggests that the core of the Tarascan state in 1520, a time of elevated lakelevel, was not a viable economic unit (Pollard, 1993; 1999).

The Development of the Tarascan State: Shifting Resources, Population Growth and Consumption Needs

Lake Pátzcuaro is a tropical, high-altitude, freshwater lake in the Central Mexican Plateau, located at 2035 m asl and approximately 360 km northwest of Mexico City. The C-shaped lake is in a small closed basin that drains a catchment of 929 km^2; the surface area covers 130 km^2 (Chacón Torres, 1993; O'Hara, 1993). Lake Pátzcuaro is an amplifier lake, and is highly susceptible to minor climatic variations (O'Hara, 1993; Street-Perrot and Harrison, 1985). A simultaneous small decrease in overall rainfall and increase in temperature and evapo-transpiration rates can result in an annual 2 m lake level difference (West, 1948).

Environmental Change

Minor climatic fluctuations in Lake Pátzcuaro's lake level have been documented by several research projects in the region (Fisher et al., 1999; McCosh et al.,1999; O'Hara, 1993; O'Hara et al., 1994). O'Hara (1991) examined the temporal and spatial variation in rates of erosion in the Lake Pátzcuaro Basin by analyzing the sediment chemistry record from 20 short cores. The magnetic susceptibility records of the cores provide evidence for a period of severe droughts during the Early Postclassic (A.D. 900-1000/1100) that resulted in a 4-5 m drop in lake level. This dry period was followed by a wetter period that resulted in a rise in lake level between A.D. 1100-1300 (O'Hara, 1991), confirming the ethnohistoric record in the RM (1980), which provides evidence for a rise in lake level to an elevation of 2039 m asl by A.D. 1380 (O'Hara, 1993).

A geomorphological study of the Lake Pátzcuaro Basin produced a tightly distributed sequence of AMS dates (A.D. 120 – 850) from a mechanically excavated trench in the southwest portion of the basin (Fisher et al., 1999). This dated sequence records rapid and continual lake level fluctuations during most of the Classic period (A.D. 120 – 775), with an apparently long-term regression of the lake after A.D. 775. The formation of the clayey soil associated with this long-term drop in lake level is buried under marsh, indicating a rise in lake level, and confirming the ethnohistoric record (Fisher et al., 1999).

Settlement pattern data from a recent survey of the southwest portion of the Basin show that from the Preclassic through the Epiclassic, settlements were generally widely scattered, small and lacustrine in orientation (McCosh et al., 1999). The location of recently exposed sites indicates that between A.D. 1000/1100 and A.D. 1300 the lake level was below 2032 m asl (Pollard, 2000). These data also suggest that many of the lacustrine sites occupied between A.D. 1000\1100-1350, were abandoned after A.D. 1350, as more communities moved away from the lakeshore (Pollard, 2000). The location of earlier sites near the lakeshore and later sites at higher elevations indicate that the lake level rose to 2040-2045 m asl (Pollard, 2000), corroborating O'Hara's (1993) estimate of 2039 m asl by A.D. 1380.

Shifts in Resource Availability

Regressions in lake level affected the available resources in the Basin by diminishing lacustrine resources and exposing rich, fertile lacustrine soils (Gorenstein and Pollard, 1983; Pollard, 1982). Conversely, when the lake level was high, it covered the most fertile land in the Basin. Pollard (1982, 1993) estimates that a rise in lake level would have submerged 5 percent of the basin, resulting in a 60 to 70 percent reduction of irrigable land. Consequent to this shift in water level, lacustrine resources (especially fish and waterfowl) would have increased while the potential to produce maize and beans would have decreased (Pollard, 1982, 1993). The settlement pattern data and geomorphological studies of soil erosion (Fisher et al., 1999) suggest that this was a time of clearance of less fertile and more marginal lands. Concurrently, the availability of deer and rabbit may have decreased as settlements moved to higher ground and cleared marginal lands, displacing local fauna (Pollard, 1982, 1993).

Population Size and Density

This shift in available resources took place at a time of dramatic increases in population size and density. The shift in settlement locations is concurrent with a marked increase in the number and size of the settlements. During the Preclassic, Classic and Epiclassic periods, the settlement of the Basin is by small communities that are widely scattered and generally lacustrine in orientation (Pollard, 1999). During the Early Postclassic, the number of sites increases (5 to 10) and the hectares occupied doubles (52 to 107), more than doubling during the Middle Postclassic (32 sites and 472 ha) (Pollard, 2000). During the Late Postclassic there is a slight drop in the number of sites (23) while the area occupied is doubled again (851 ha) (Pollard, 2000), suggesting larger and denser settlements.

Shifts in Socio-Political Organization

The absence of regional authority with decision-making power at a time of rapid population growth led to competition between local elites for control and access to diminishing resources. This competition resulted in the formation of highly nucleated populations (Pollard, 1993). The RM (1980) indicates that this competition was the cause for the succession of wars that concentrated economic and political power in the hands of the *uacúsecha* elites.

Major shifts in socio-political organization begin to take place in the Classic Period. Between A.D. 500 and 700 there were elites in centers around Central Michoacán with a broadly shared tradition from the Late Preclassic Chupícuaro culture (Pollard, 1996; 1999). The mortuary tradition of this period is dominated by primary extended burials, but by the Late Classic Period, individuals were buried in group tombs, used over multiple generations. Burials were associated with preciosities imported as finished goods of raw materials derived from many parts of Mesoamerica. Cranial deformation, dental mutilation and exotic grave goods served to distinguish the elites at these centers from the surrounding populations (Pollard, 1996). Access to exotic goods through participation in the macroregional exchange system marked local elite status. The importation of these exotic finished goods indicates that elites derived their social and economic power through linkages to other parts of western Mesoamerica (Pollard, 1996; 1999). Settlements have ball courts and mound groups with sunken plazas.

The breakdown of Classic period exchange networks and the re-organization of the Mexican Highlands between the Early and Middle Postclassic (A.D. 900-1300) brought about another shift in socio-political organization (Pollard, 1996). Large nucleated upland sites appear, grow and expand, while smaller, less defensible lakeshore sites are abandoned (Pollard, 1996). Centralization, social stratification and economic and political integration begin between A.D. 1100-1350, leading to the formation of the Tarascan state (Pollard, 1996).

In the Late Postclassic (A.D. 1350-1525) sites appear in less defensible locations near the lakeshore. New areas of the uplands (*malpaís*) are settled. There is a dramatic growth in size and complexity of large urban centers with new monumental construction. The Lake Pátzcuaro Basin becomes the cosmological center in the state religion. Elites no longer mark their status with imported exotic finished goods. Instead, they mark their status with goods that link them to the Tarascan elites and to Tarascan state religion (Pollard and Cahue, 1999).

Dietary Needs and Food Availability

By comparing productivity estimates and dietary needs Pollard (1982) showed that the Lake Pátzcuaro Basin produced insufficient maize to feed a population consuming a hypothetical Tarascan diet. From ethnohistoric documents, we know that the Tarascans utilized a range of foods that included more than fourteen genera of domesticated plants, four genera of local fish, various local waterfowl, deer, small mammals, domestic turkey, condiments (cacao, honey, salt) and lime for maize preparation (Gorenstein and Pollard, 1983). Because there is little direct evidence for the use of these foods by the Lake Pátzcuaro Basin populations, Pollard (1982) proposed a hypothetical diet based on foods consumed in the basin in the early sixteenth century and on ethnographic data. In all probability, this diet reflected the consumption patterns of Tarascan elites. While it is likely that the non-elite population consumed a different diet, this difference is not well documented. Therefore, this diet will be referred to as the Tarascan diet.

Theoretically, this elite diet would have provided approximately 2400 usable calories. Pollard's (1982) estimates are based on a one third loss in nutrients due to cooking procedures. The caloric content of the diet after taking this loss into account is derived from 600g of maize and amaranth combined (1950 cal, 81.3%), 88g of beans (176 cal, 7.3%), 100g fish (67 cal, 2.8%), and fruits and vegetables (200 cal annual average, 8.3%) a day (Gorenstein and Pollard 1983; Pollard, 1982). Maize/amaranth, beans and fish, combined, constitute approximately 90% of the *total calories* in this diet, while maize/amaranth (C_4 foods) alone constitute approximately 71% of *total diet* by weight. The proportion of maize/amaranth in this diet is comparable to that in diets estimated by Brand (1951) for ethnographic populations in the Lake Pátzcuaro Basin, Ivanhoe (1978) for the protohistoric Texcoco population, and Ortiz de Montellano (1990) and Whitmore (1992) for the Aztec in the Basin of Mexico.

For 80,000 people to consume this hypothetical diet, the following annual amounts of food would be needed: 17,520,000 kg maize/amaranth; 2,560,000 kg of beans; 2,080,000 kg of fish; 832,000 kg of meat (primarily deer, rabbit, duck, and turkey)

(Pollard, 1982). The estimated productivity figures for these food items are not sufficient to meet dietary needs, as there were only 9,821,200 kg of maize/amaranth, 2,331,050 kg of beans, 4,732,800 kg of fish, and an average of 410,000 kg of meat (deer, rabbit, duck and turkey combined) produced (Pollard, 1982). Of these items, only fish was available at a surplus.

Meeting Dietary Needs: Dietary Change, Agricultural Intensification, or Economic Exchange?

The rapidly growing population in the Lake Pátzcuaro Basin may have responded to declining maize availability by changing their diet, intensifying agricultural production, or participating in economic exchange networks to obtain the needed maize (and other resources).

Dietary Change

It is unlikely that a major shift in diet took place because maize most likely provided 80% of the *caloric* dietary intake and the available alternative foods, while abundant, could not have replaced these energy requirements (Ortis de Montellano, 1990; Pollard, 1993; Whitmore, 1992; Whitmore and Williams, 1998). Assuming equal consumption levels for all members of the population, regardless of age, sex, or social status, each individual would have a diet that is calorie-energy deficient, but high in protein (Table 2). Protein levels that are this high have been to hypercalciuria, osteopaenia, and osteoporosis (Linkswiler, et al., 1974). Additionally, a calorie-deficient diet would have serious health and social consequences.

TABLE 2

Lower Calorie Diet			
	Amount g/day	**Calories [(a)] cal/day**	**Protein [(a)] g/day**
Maize	336	1202.88	28.22
		358cal/100g	8.4g/100g
Beans	79	270.97	17.93
		343cal/100g	22.7g/100g
Fish	162	108.54	100.28
		67cal/100g [(b)]	61.9g/100g
SUBTOTAL		**1582.39**	**146.43**
Substitute			
Deer	14	21.7	4.13
		155cal/100g	29.5g/100g
		1604.09	**150.56**
Duck	14	16.1	3.26
		115cal/100g	23.3g/100g
		1598.49	**149.69**
Rabbit	14	13.86	2.57
		99cal/100g	18.4g/100g
		1596.25	**149**
Turkey	14	37.52	2.81
		268cal/100g	20.1g/100g
		1619.91	**149.24**
Requirements [c]		**2200**	**45**
Males [d]		**2475**	**80**
Females [d]		**1920**	**70**

[a] Cravioto et al., 1945; Flores et al., 1960

[b] Gorenstein and Pollard, 1983

[c] Ortiz de Montellano (1990) after FAO-WHO (1985)

[d] Whitmore and Williams (1998)

A population consuming a calorie-deficient diet would have lacked the necessary energy to engage successfully in military raids, activities associated with the development and expansion of the state, and more importantly, food production. Changing the diet to consume what was available would compromise the nutritional status of the population and increase the risk of acquiring infectious diseases. Calorie-energy deficiency affects the work capacity, fertility, mortality and morbidity of a population; disrupting the social, political and economic structure of the community (Allen, 1984). It is unlikely that a nutritionally compromised population would have had the work capacity necessary for the construction and expansion evidenced in the large civic-ceremonial centers that appear during this time. Furthermore, fertility rates do not seem to have been a problem, as evidenced by the dramatic increase in population size and density.

Agricultural intensification

An alternative to dietary change could have been to intensify the cultivation of available irrigable land, and to clear and cultivate less fertile and more marginal lands. Geomorphological and archaeological data show that intensive agriculture, while not extensive, was practiced on terraces constructed on hill slopes between Tzintzuntzan and Ihuatzio; and on non-lacustrine, irrigable lands (Polard, 1999). There is no evidence for *chinampa* (raised fields) construction (Pollard, 1999), but agricultural canals ressembling those described by West (1947) have been documented.

The radiocarbon dates associated with the agricultural features (canals) found in the Lake Pátzcuaro Basin indicate that they were constructed during the period of low lake levels when population densities were relatively low, and before the formation of the state (Fisher et al., 1999). These dated canals provide the earliest evidence of agricultural features in the Lake Pátzcuaro Basin, and represent the emergence of agricultural intensification in the region.

Economic Exchange

In contrast, a more likely response seems to have been the acquisition of needed foods from outside the basin given that maize was not only of nutritional value, but also of symbolic significance to the Tarascans (as it was to other Mesoamerican societies) (Ortiz de Montellano, 1990; Pollard, 1993). Given that the Tarascan state was not a viable economic unit, it could have only existed through the establishment of mechanisms of economic exchange (Pollard, 1982; Pollard; 1993).

Evidence for economic exchange in the Tarascan state can be found in the ethnohistoric record. Market exchange is not amply recorded in the *Relación de Michoacán* (1980) or in the *Relaciones Geográficas*, but the RM (1980) shows a drawing of the *Asajo* market. Pollard (1993) cites several terms from the Gilberti (1559) dictionary, related to market exchange. These are merchant (*mayapeti*), marketplace (*mayepeto*), trade (*mayapecua*), and marketing (*mayapenit*). The RM (1980) indicates that three major markets serviced the Lake Pátzcuaro Basin population during the Late Postclassic (A.D. 1350-1520). Two of these were located within state administrative centers at Tzintzuntzan and Pareo; the third, Asajo, was located northwest of the basin (Gorenstein and Pollard, 1983).

Documented goods and services flowing through the markets include maize, beans, chile peppers, amaranth, local fruit, ducks, local birds and feathers, fish, cotton cloth and clothing, slaves, prepared food, medicinal plants, and household services (grinding maize, carrying water, etc.) (Pollard, 1993). Undocumented goods believed to have flowed through market networks include squash, nopal cactus, dogs, maguey fiber, wood products, chert, opal, copal, salt, lime, rabbit, and turkey among others (Pollard, 1993). The availability of deer was limited in the Basin by restrictions to their natural habitat, and although this resource is not documented in market network context, its general use by the population indicates it may have flowed through the markets (Pollard, 1993).

While non-elites obtained their goods through the markets, elites obtained goods through state-controlled institutions (tribute, state long-distance merchants, and although poorly documented, local tribute through outright ownership to production) (Pollard, 1982). The Tarascan state had a vast, centralized and hierarchically organized tribute network (Pollard, 1993). The bulk of goods from various regions of the state passed through various levels up to the capital, Tzintzuntzan, where they were stored in central warehouses (Pollard, 1993). The stored items were used for the Tarascan nobility at Tzintzuntzan, foreign emissaries, and religious functionaries. In addition, these goods served as emergency stores for the local population and during periods of war, maintained the large armies (Pollard, 1993). The most common items on tribute lists were maize and cotton cloth and clothing. Also on the lists were slaves, sacrificial victims, household services, metal objects, cacao, gourds, gold, silver and copper. Salt, beans, chile peppers, rabbit, turkey, honey, maguey wine, feathers and ceramic vessels appeared in both market and tribute contexts (Pollard, 1993).

The state claimed ownership of the most productive lands in the Basin, and used them to produce the food directly consumed by the royal household and Tarascan nobility. The products grown on these lands included maize, beans, chile peppers, squash, amaranth, fruit and tobacco. The Tarascan nobility may have also held exclusive rights to firewood, lumber, deer and rabbit from local forests (Pollard, 1993).

Although not well documented, local tribute was probably a source of manufactured goods and services. Since much of the Basin's best land supported the elite, a large portion of the foods forming the majority of the non-elite diet (maize and beans) must have been imported through market networks (Pollard, 1999). In settlements with immediate access to prime agricultural lands, marshes, or fishing zones people could exchange surpluses for needed items (Pollard, 1993). In exchange for items flowing into the Basin, the Tarascans exported some goods and services. Fish was the primary food commodity exported from the Basin in exchange for maize, amaranth, beans, and chili peppers through the market network, and is associated with lakeshore populations devoted to the harvesting of fish. In addition to fish, only manufactured goods seem to have flowed outside the Basin.

In return for tribute and state control of land, forests, and mineral resources, the elite exported "elite culture," state religion, and administrative organization; maintaining and defending the state's borders (Pollard, 1993). The flow of services and goods within the Tarascan state served to create and maintain uneven relationships between the Lake Pátzcuaro Basin and other regions of the state; and between Tzintzuntzan and other administrative centers within the Basin (Pollard, 1993).

The elite appear to have used economic and political power as a mechanism to cope with environmental change and food insufficiency, while the rest of the population adapted by specializing in fish production and manufactured goods for exchange in regional markets (Pollard, 1982; 1993; 1999).

Assessing the Nutritional Adequacy of the Hypothetical Tarascan Diet

A significant portion of the foods imported for the elite included sources of meat protein, such as deer and rabbit, indicating that the elite had access to adequate sources of protein. The nutritional value of the Tarascan diet proposed by Pollard (1982) was reevaluated using the nutritional standards and requirements used by Ortiz de Montellano (1992). This reevaluation shows that the Tarascan diet would have provided approximately 67g of animal protein (132.27g of total protein) and 2516 cal when the source of animal protein is fish. When fish is substituted with 100 g of other sources of animal protein, the total protein in the diet averages 93g, ranging from 88.77g with rabbit to 99.87 with deer. The caloric value averages 2609 cal, ranging from 2548.84 cal with rabbit to 2717.84 cal with turkey. This diet is clearly above the safe levels of protein and energy intakea defined by the Food and Agriculture Organization (FAO/WHO/UNU, 1985) of 2200 cal and 45g of protein. The adequacy of the protein in many maize staple diets, however, may be low in the absence of complementing legumes, or lime treatment during preparation; countering the general assumption that if energy needs are met, the need for other nutrients will also be met (Ulijaszek, 1995).

Maize protein is deficient in lysine and tryptophan, but has fair amounts of sulphur-containing amino acids (methionine and cystine). The convertion of tryptophan to niacin is negatively affected by high proportions of leusine, raletive to isoleucine, in diet heavily dependent on maize. Alkaline cooking techniques (such as lime treatment) ameliorates the production of niacin by increasing the amount of isoleucine in maize (Katz, et al., 1974). Alkaline cooking increases the amount of niacin and improves the quality of the maize protein, but it also decreases its overall nutrient content (Araya et al., 1981; Bye, 1981; Katz et al., 1974; Ortiz de Montellano, 1990).

In addition to alkaline cooking of maize, dietary tryptophan and niacin can increased by consuming a maize-bean dietary complement. Protein in legumes is a relatively rich source of tryptophan and niacin, but is low in sulfur-containing amino acids (Bye, 1981). A maize-bean dietary complement, however, is deficient in ascorbic acid, and riboflavin (Araya et al., 1981; Bye, 1981). Leafy vegetables such as amaranth ("quelites") complement the maize-bean diet in these nutrients (Bye, 1981).

The consumption of whole fish adequately fulfills calcium requirements, increases the total protein and improves the quality of dietary protein (Mayer, 1962). While fish was clearly the primary source of animal protein, the Tarascan diet included meat sources of protein (deer, rabbit, turkey, and duck) as evidenced in the RM (1980). Pollard proposed two non-fish meats per week (Pollard, 1982). Squash fruits contribute vitamins A and C, and minerals to the diet (Araya et al., 1981).

The nutritional composition of the Tarascan diet indicates that it adequately met nutritional requirements, and was likely, not a significant source of nutritional illnesses. Because of its complexity, and its heavy dependence on a relatively small number of foods (maize, beans, fish), however, the Tarascan diet would have been very susceptible to changes in the availability of these foods, regardless of magnitude. If the proportions of foods in the Tarascan diet shifted enough to alter their nutritional complementarity, individuals would have been more susceptible to infections due to the synergistic effect between nutrition and infectious illnesses. If the population of the Lake Pátzcuaro Basin was unable to secure enough food to maintain the Tarascan diet, it may have experienced an increase in infectious diseases and developmental defects secondary to nutritional deficiencies.

Health in the Tarascan State

Evidence for health in the Tarascan state is available from the ethnohistoric documents and from a very limited number of skeletal studies. Ethnohistoric documents were used in a study of Tarascan medicine and medical belief systems (Sepulveda y H, 1988). There were more than twenty terms in the Gilberti (1975) dictionary describing accidents or trauma as a cause of illness, four terms for emotional ailments, more than forty terms for pain, blindness and cataracts ("clouded eyes"). There were more than forty-five terms for infectious or contagious diseases, although many of the terms used describe symptoms of diseases imported by Europeans. Other conditions listed include deliberate abortion, animal bites (snake and insects) and burns, but none referring to hunger or malnourishment.

Osteological evidence of health within the Tarascan state is available from only two studies; one conducted by Uruñuela (1996) at the site of Atoyac in the Lake Sayula Basin, and one currently under way at the site of Urichu in the Lake Pátzcuaro Basin (Cahue, 1998).

TABLE 3

Frequency of Affected Indiviudals with Skeletal and Dental Indicators of Health

	Periostitis		Dental Caries		Enamel Hypoplasias	
	PT	T	PT	T	PT	T
ATOYAC	13.72% n= 51	7.7 n= 104	73.33% n= 30	51.66% n= 60	90.00% n= 30	61.66% n= 60
URICHU	12.50% n= 16	5.26% n= 19	31.25% n= 16	68.42% n= 19	25.00% n= 16	26.31% n= 19

The preliminary data in Table 3 show that in Atoyac, the frequency of individuals affected with carious lesions decreased over time, while at Urichu, it increased. The higher frequency of affected individuals in the Tarascan Urichu may reflect the age distribution of the individuals in the sample. In the Pre-Tarascan sample, 62.5% of individuals in young adulthood (20-34 yrs) and under, including adolescents and children. In contrast, the percentage of individuals in these age brackets in the Tarascan sample at Urichu is only 21% with only two children in the sample. Sixty eight percent of the Tarascan sample is middle adulthood, with seven individuals between 35-49 years, and four over fifty years.

Enamel hypoplastic defects show a marked decline over time in the Atoyac sample, suggesting an improvement in the ability of children to overcome physiological insults and survive into adulthood. Compared to the Atoyac populations, the Urichu populations show lower frequencies of individuals with enamel hypoplastic defects, and little difference over time, suggesting that the Urichu population was better able to cope

with physiological insults. None of the children in the Pre-Tarascan Urichu sample have enamel hypoplastic defects

The frequencies of individuals with periosteal lesions show a temporal decline at both sites, and the differences between the two sites for both time periods are negligible. The periosteal lesions identified at these two sites provide evidence of non-specific infectious processes. The temporal decline in periostitis prevalence in the Urichu case is of interest because it is accompanied by an increase in population size and settlement. This pattern highlights the argument, so eloquently made by Ortner (1992) regarding the interpretation of skeletal infectious lesions. Very rarely do acute infectious illnesses and viral infections affect the skeleton. Almost all infectious conditions that are evident in the skeleton are chronic diseases and of bacterial etiology (Ortner, 1992). The higher prevalence of periostitis in the Pre-Tarascan samples may indicate the presence of chronic bacterial infectious diseases in individuals who managed not to be overwhelmed by the infectious agent, but were unable to produce an immune response that would effectively eliminate this agent from the body. As populations grew larger and denser, chronic bacterial infections could have become more acute, killing their hosts before there was time for skeletal lesions to develop.

Given the interaction between nutritional status and infectious diseases, infectious disease should be more prevalent among populations whose diets fail to meet nutritional requirements. Nutritional status, however, is not the only factor affecting the prevalence of infectious diseases; the individual's immune response, the age of onset, the biology of the infectious agents and the social conditions contributing to its transmission are also important (Ortner, 1992).

The preliminary data presented here, although limited, seem to indicate that the Tarascan samples experienced more acute infectious diseases. Given this observation, a study of infectious diseases among these populations would be incomplete without an understanding of their nutritional status. An evaluation of the Tarascan diet will be the first step toward this goal.

The overriding hypothesis in this dissertation is that the Tarascan elite were able to use their political and economic power to obtain food from outside the Lake Pátzcuaro Basin, supplementing goods extracted from the labor of local populations as they produced food to meet tribute obligations.

To evaluate the effect of environmental change, food availability and economic power on the diet of Tarascan elites, two analytical temporal units were determined: Pre-Tarascan and Tarascan. The Pre-Tarascan period is temporally defined from the beginning of the Classic period (A.D. 350) up to the time of political and economic unification of the Lake Pátzcuaro Basin (ca 1300). The Tarascan period is defined from the time of political and economic unification of the Lake Pátzcuaro Basin to the time of contact with Europeans (A.D. 1525).

In summary, the available data for the Lake Pátzcuaro Basin show that these two analytical units differ in environmental conditions, agrarian potential, settlement patterns, population size and density, economic exchange and socio-political organization.

The Pre-Tarascan period (A.D. 350-1300) (Figure 2), is associated with a low lake level, high agrarian potential, and low lacustrine resources. During this time, population size and density are relatively low, and elites are deriving their power from links to outside elites, marking their status with exotic luxury items form outside the

Basin. The presence of two agricultural intensification features (canals) at a time of relatively low population density indicates that in the Lake Pátzcuaro Basin, the emergence of agricultural intensification is not associated with demographic pressure as proposed by Boserup (1965). Instead, agricultural intensification seems to signal the production of surpluses, which may have been used by elites as tools to acquire exotic goods as they attempted to consolidate their power (Fisher et al., 1999; Hayden 1991).

In contrast, the Tarascan period (A.D. 1300-1525) (Figure 3) is associated with rising lake levels, reduced agrarian potential and high population densities. The populations of the Basin are politically and economically unified, and elites are hierarchically organized. Elites reside in administrative centers established throughout the Basin, their power is derived from ties to Tzintzuntzan, and they mark their status with locally crafted items that resemble those used and worn by the Tarascan nobility.

The preliminary data available on the health of Pre-Tarascan and Tarascan populations in the region suggest a pattern of spatial and temporal variation in the frequency of affected individuals for dental carious lesions, enamel hypoplastic defects, and periosteal lesions. The decline in periosteal lesions coupled with a significant demographic explosion in the region was most certainly affected by the nutritional status of the population. Although a decline in nutritional status renders a population susceptible to infectious diseases, the ethnohistoric and ethnographic data do not support this proposition. To determine whether or not the nutritional status of Tarascan elites declined, this dissertation used stable isotope analysis of bone collagen to detect spatial and temporal dietary patterns, with the expectation that the diet of elites did not change through time and that the diet of elites at various administrative centers would be the same. Two pooled samples were formed, and differences in their isotopic values were compared. Nonparametric statistics were used to evaluate the significance of the findings. Chapter four describes the sampling criteria, the scientific hypotheses formulated for this study, and the analytical methods used to evaluate the rejection of the null hypotheses.

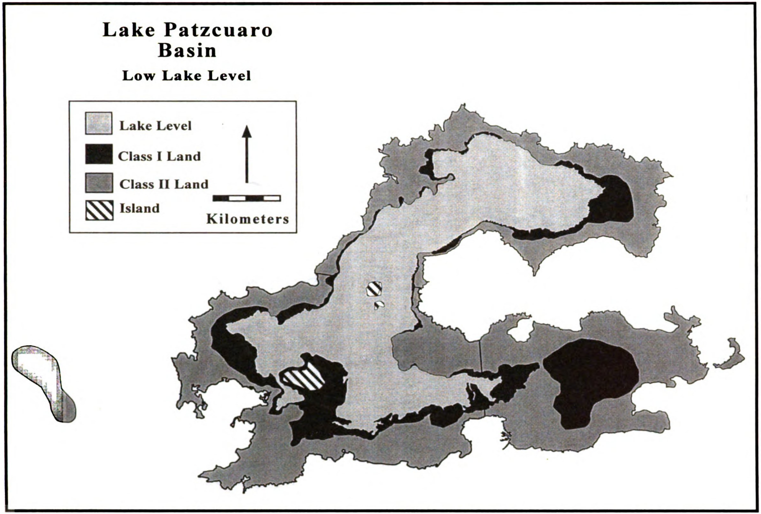

Figure 2. Map of Lake Patzcuaro showing the amount of Class I and Class II land exposed when the lake level is low (modified from Pollard and Cahue, 1999).

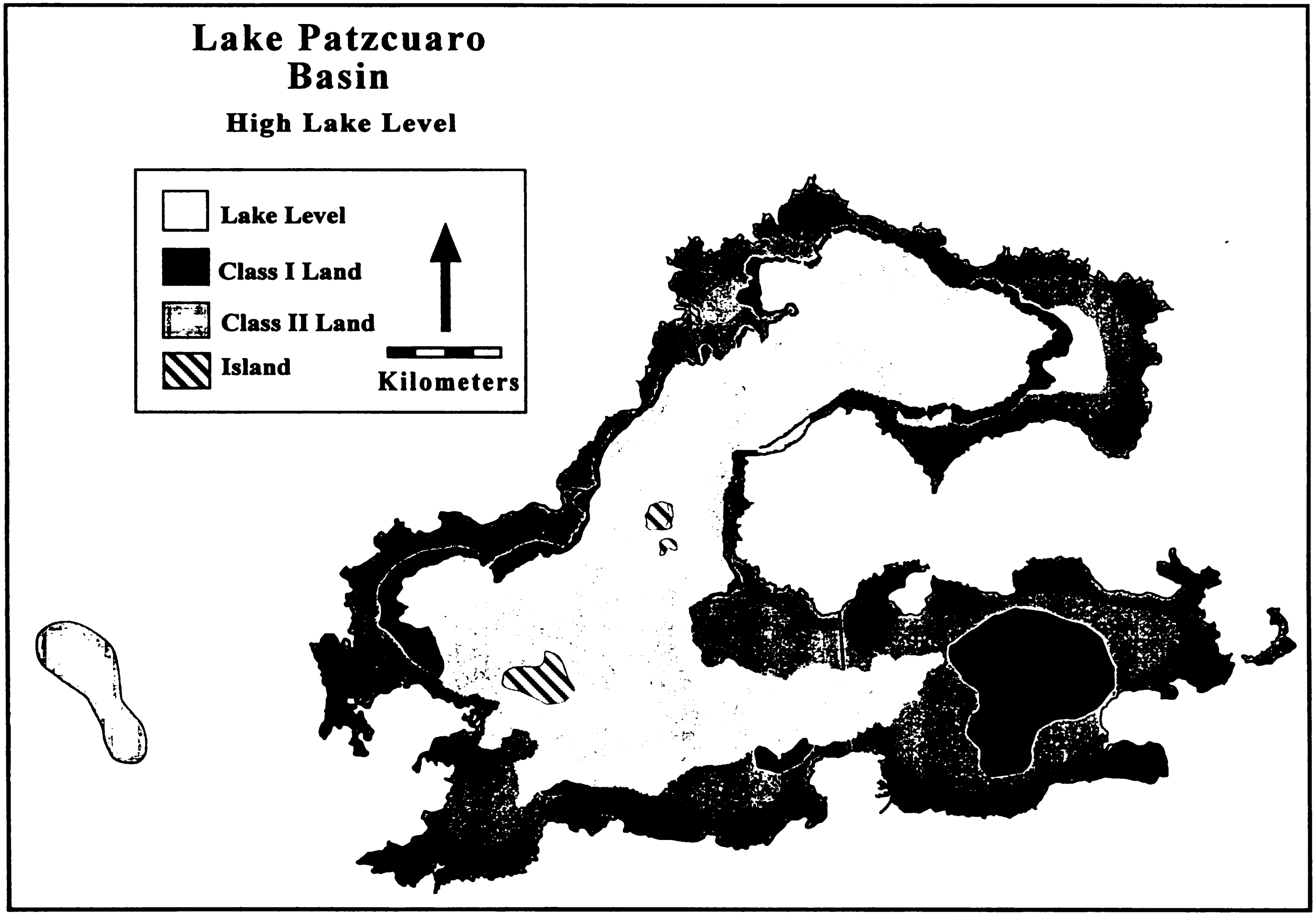

Figure 3. Map of Lake Patzcuaro showing the amount of Class I and Class II land under water when the lake level is high (modified from Pollard and Cahue, 1999).

Chapter 4

HYPOTHESES, METHODS AND MATERIALS

The Tarascan state developed at a time when the population was growing, settlements were becoming denser and the lake level was rising. Under these conditions, the Lake Pátzcuaro Basin as unable to produce enough maize to feed its population. Considering the number of words in the Tarascan language for infectious illnesses and associated symptoms (Sepúlveda y H., 1988), it is entirely possible that these conditions also resulted in an increase in infectious diseases.

If the Tarascan elite used their political and economic power to obtain foods and resources that were not available in the Lake Pátzcuaro Basin, their dietary intake of maize should be close to that in the proposed Tarascan diet. As discussed in Chapter 3, this diet adequately fulfills energy and protein requirements (Pollard, 1982). Therefore, the nutritional status of the Tarascan elite could not have compromised their health, yet the limited data available on skeletal markers of health suggest a sift in diet (dental caries decrease at Atoyac and increase at Urichu) and an increase in the incidence of acute infectious illnesses (periosteal lesions decrease at both sites). Given the synergistic effect between nutritional status and infectious illnesses, knowledge of the Tarascan diet and its nutritional adequacy are essential for understanding the effect of state formation on the health of individuals.

In this study, dietary patterns among elites were measured using stable isotope geochemistry. It is important to note that the aim of the study is not to reconstruct the actual diet, but to record the carbon and nitrogen isotopic signatures of one group relative to another. An actual dietary reconstruction would essentially test the accuracy of the proposed hypothetical diet; and although desirable, this test is not yet possible given the limited information available about the isotope ecology of the region.

Theoretically, an increased dependence on C_4 foods (maize and flesh of C_4 consumers) leaves a $\delta^{13}C$ signature in bone collagen that is higher than that for consumers of C_3 foods and the flesh C_3 consumers. A diet dependent on leguminous plants will leave a $\delta^{15}N$ signature in bone collagen that is relatively low, although current estimates indicate that legumes (like beans) must provide approximately 17% of the diet before they produce a clearly discernible isotopic signature, typically, a difference in $\delta^{15}N$ of 2‰ (Schwarcz et al., 1985).

Differences in $\delta^{15}N$ values may be the result of shifts in trophic levels in the diet. This phenomenon is best recognized in studies of carnivory versus herbivory, where the $\delta^{15}N$ differences in bone collagen are expected to be approximately 3‰ (Schoeninger and Moore, 1992). Most human studies, such as the present one, are concerned with whether people ate 10 versus 25% meat, for example (Schoeninger and Moore, 1992). Current estimates suggest that humans could not survive on greater than 40% meat protein consumption, with few exceptions such as the Eskimos and the Dogrib (Draper, 1977; Swathmary et al., 1987). Most human populations do not consume more than 25% of their calories as meat protein (Noli and Avery, 1988). If the relationship of $\delta^{15}N$ of bone collagen and diet were linear, a difference in meat consumption of 15% (from 10 to15%) would leave a $\delta^{15}N$ signature in bone collagen that is less than 0.5‰ (Schoeninger and Moore, 1992). To detect such shifts, samples that are very large and have very little within group variation are necessary. In spite of these limitations, $\delta^{15}N$

values are useful in determining relative dependence on meat (greater or lesser), although the estimates must be regarded as crude (Schoeninger and Moore, 1992). Bone collagen $\delta^{15}N$ values seem to be more useful in determining differences between two ecosystems providing dietary protein (e.g., marine *versus* terrestrial, coral reef *versus* deep ocean, and lacustrine *versus* terrestrial).

MATERIALS

A regional approach to the study of the diet of the population living within the Tarascan territory is justified by the cultural, linguistic and environmental homogeneity within the region (Pollard, 1993). Ideally, this study would include a temporal comparison of elite and non-elite individuals' diets. It is unfortunate, however, that to date, non-elite burials from this region are not available for study.

Collections from four archaeological sites located within the Tarascan territory were selected to form two samples; Pre-Tarascan (PT) (A.D. 1 - 1300) and Tarascan (T) (A.D. 1300 - 1525). The selection of sites was based on a three month pilot study designed to conduct archival research to: 1) identify available skeletal materials from the region, 2) locate excavated skeletal collections, and 3) assess the collections for degree of skeletal fragmentation and bone preservation.

Several additional collections were surveyed in the study. While many collections met the criteria for inclusion, they were not available for study at the time, although future access to these collections is possible. In the Zacapu Basin, several skeletal collections should be available for future study. From the Classic period, the sites of Loma Alta and Guadalupe provide excellent collections of skeletal remains from discrete and commingled contexts. The Loma Alta collection consists of thirty-one funerary urns with cremated remains, one funerary urn with non-cremated remains, six primary burials and seven secondary burials (Arnauld, et al., 1993). The Guadalupe collection consists of the commingled remains of at least 40 individuals with good preservation (Gervais, 1989). Also available form the Zacapu Basin are the Postclassic collections from El Palacio and Milpillas. The El Palacio collection , excavated by Lumholtz and Hrdilcka (1898), is curated in the Department of Anthropology of the American Museum of Natural History in New York, City, New York. The Milpillas collection is under the custody of the *Centro de Estudios Mexicanos y Centro Americanos* (CEMCA) in Mexico City, Mexico, and it was studied by Olivier Puaux (1989), as part of his doctoral theses, from the University of Paris 1, in Paris, France.

In the Cuitzeo Basin two large skeletal collections have been recovered from the Classic to Postclassic site of Tres Cerritos and the Postclassic site of Huandacareo. Both sites were excavated by Dr. Angelina Macias-Goytia, Researcher at the INAH - Centro Regional, Michoacán. The Tres Cerritos collection represents the remains of over 50 individuals, from multiple burials in a tomb. The remains are reported to be in poor condition, with very poor preservation (Macias-Goytia and Vackimes-Serret, 1989). The site of Huandacareo dates to the Postclassic. Over 90 individuals are represented in this collection from 88 individual and multiple burials (Macias-Goytia, 1990).

Outside the lake basins, two sites have yielded important skeletal collections, neither of which is radiometrically dated, but both are assumed to date between the Classic and the Epiclassic. These sites are Santa Maria on the outskirts of the city of Morelia, and Tingambato (Tinganio). The Santa Maria collection is curated at the INAH-

Salvamento Arqeológico warehouses in the State of Mexico, outside of Mexico City, Mexico, and it may represent more than 35 individuals. The number of individuals represented in the multiple use tomb at Tingambato has been the subject of debate (Piña Chan and Oí, 1982). One study estimates the number around 100 individuals (Lagunas Rodriguez, 1987), but in a recent study Pereira (1997) estimates a minimum number of individuals (MNI) of 36 based primarily on the calvaria (36), the mandibles (35) and tehfemora (32 right and 24 left). The materials are housed in the National Museum of Anthropology and History in Mexico City, Mexico. Requests were made to access all of these collections, unfortunately, they were not available at the time this study was conducted.

Four sites were available for study, three in the Lake Pátzcuaro Basin (Tócuaro, Tzintzuntzan, and Urichu) (Figure 4), and one in the Sayula Basin (Atoyac) (Figure 1). All the sites were administrative centers of various ranks under the direct control of the state (Pollard, 1993).

Tzintzuntzan was the capital of the Tarascan state, and as such it held control over the Tarascan Empire, placing it at the top (Rank 1) of the state's administrative hierarchy. Tzintzunztan was also the administrative center of the Lake Pátzcuaro Basin, and as such, it was designated a Rank 2. Eight other administrative centers were established within the lake basin. Each one was governed by *achaecha* (or *señores*) and reported directly to the royal dynasty in Tzintzuntzan. These administrative center were: Erongarícuaro, Urichu, Pechátaro, Pareo, Pacandan-Xarácuaro, Itziparamucu, Uayameo and Pátzcuaro. Each of these centers administered several dependent villages and hamlets, who reported directly to them and had no direct contact to Tzintzuntzan. Each unit would have had

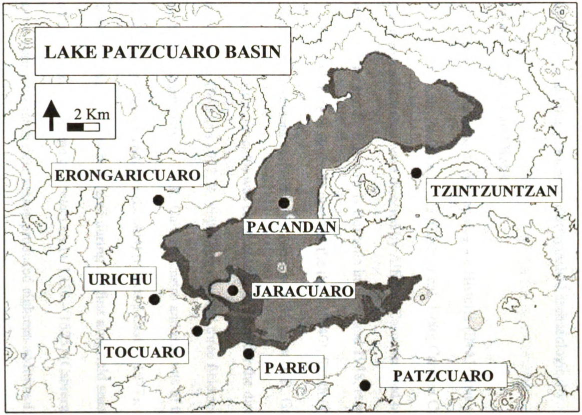

Figure 4. Map of the Lake Patzcuaro Basin showing location of Tzintzuntzan, Urichu and Tócuaro (modified from Pollard and Goresntein, 1983).

between one and sixteen dependent settlements, representing between 2,500 and 9,800 people. Within the administrative hierarchy of the state these centers were Rank 3 centers. Eighty two settlements were below a Rank 3, and associated with specific archaeological sites. Unfortunately, many level 4 and 5 communities are not associated with specific sites, and thus, cannot be distinguished archaeologically.

Tzintzuntzan – Rank 1 and Rank 2

The Instituto Nacional de Antropología e Historia (INAH) has conducted over ten field seasons at this Late Postclassic site (Castro Leal, 1986; Cabrera Castro, 1977, 1987). The first and second seasons were directed by Alfonso Caso, assisted by E. Noguera in 1929, and J. Acosta and D. Rubín de la Borbolla in 1937 and 1938, respectively. (Cabrera Castro, 1977). Rubín de la Borbolla directed the third (1940), fourth (1942), fifth (1943-44) and sixth (1946) seasons assisted by H. Moedano, M. Acosta, R. Galí, and R. Piña Chan. One brief season (seventh) was conducted in 1956 under the direction of R. Orellana. Btween 1962 and 1977, R. Piña Chan directed three field seasons (eighth, ninth, and tenth), assisted by K. Oí, R. Cabrera Castro and students of the *Escuela Nacional de Antropología e Historia* (ENAH) (Cabrera Castro, 1977).

Forty-one burials were recovered during the first nine field seasons, and date from the Late Postclassic to the time of contact (A.D. 1350 – 1525) (Cabrera Castro, 1987). Excavations during the tenth field season produced eighteen additional burials (17 at the base of yacata 3 and 1 in structure F), bringing the total documented number to fifty-nine Cabrera Castro, 1987), although this figure has been questioned (Castro Leal, 1987). In general, male burials were associated with clay pipes and obsidian ear and lip plugs, and the female burials with large numbers of polychrome ceramics (Castro Leal, 1986). The burials present a high incidence of dental alteration, types A1 and A2 (Romero Molina, 1986), and cranial deformation, a characteristic explicitly referred to as a marker of elite status in the *Relación de Michoacán* (1980:187).

The burials located during the survey for skeletal remains were mostly those excavated during the 10th field season, and were made available by, the archaeologist, Lic. Rubén Cabrera Castro, Research Project Director at the archaeological zone of Teotihuacan, INAH. Figure 5 shows the areas of the site where excavations have been conducted (structures B, F, G). Not shown are excavation blocks A, C, D, and E.

The samples included in this study were obtained from the materials recovered during the tenth field season. Although the direct association between sample and burial location is lost, a map (Figure 6) was constructed utilizing original field notes and sketches provided by Cabrera Castro indicating the location of burials recovered during the tenth season. Tentative associations were made by correlating the labels in the boxes and on the various bags within the boxes with field notes and drawings. This map illustrates that all samples were taken from burials located on the main platform. The associated goods and cranial deformation (currently under analysis) also indicate that these were elite individuals.

Tzintzuntzan Ossuary

An ossuary off the northeast side of the main platform (Figure 5) was located during the third field season (Rubín de la Borbolla, 1941). In 1992, a trench was accidentally placed though the ossuary by a field worker, revealing the stratigraphy described by Rubín de la Borbolla almost 50 years earlier. The ossuary contains disarticulated remains, with an interesting stratigraphy. The first 70 cm consist of fragmented irregular skeletal elements like vertebrae, scapulae, ribs, and small cranial fragments. Below this layer, there is a layer of calcined bone fragments containing obsidian blades twisted by the heat of the fire. Below this layer there is layer of disarticulated cranial bones and long bones, most of which are relatively complete.

This unfortunate accident also made it possible to examine a sample of the skeletal remains contained in the ossuary. At the request of Efraín Cárdenas, Head Archaeologist at the INAH Centro-Michoacán, the skeletal material was crudely inventoried and a gross count of skeletal elements was submitted to him (Cahue, unpublished data). The skeletal remains are generally more robust than those excavated from the main platform, and from Urichu and Tócuaro. The preservation of the non-burnt bone is excellent. There is considerable porotic hyperostosis, cribra orbitalia, and infectious lesions (periosteal lesions, osteomyelitis).

The differences in morphology and pathology between these remains and those excavated elsewhere suggest that the ossuary does not contain the remains of Tarascan elites. Ethnohistoric accounts suggest that the ossuary contains the remains of sacrificial victims (Rubín de la Borbolla, 1941). Sacrificial victims would have been captured warriors and non-Tarascan elites captured during war, but Tarascan individuals who offended the king could have also been killed at Tzintzuntzan, as a matter of justice and not a sacrificial offering, and deposited in the ossuary.

Urichu - Rank 3

Urichu is located in the Lake Pátzcuaro Basin (Figure 4), on the northwest portion of a lava flow (*malpaís*) south of the modern town of San Francisco Urichu (Figure 7). Urichu is ethnohistorically documented to have been an elite center prior to the formation of the state, and one of the eight administrative centers directly answering to Tzintzuntzan after the state emerged (Pollard and Gorenstein, 1982). The site covers more than 90 ha and contains at least three public zones with pyramid-plaza complexes, deeply stratified cultural deposits, and intact human burials. Nine areas of the site have been defined, and excavation units have been opened in three these: area 1, area 2, and area 5. Area 5, at the southern end of the site was occupied from the Classic (A.D. 400) to the Late Postclassic period (ca. A.D. 1350), area 2 during the Middle Postclassic and Late Postclassic (A.D. 1000/1100 – 1350), and area 1 during the Early Classic and Late Postclassic (ca. A.D. 400 – 1525).

Excavations in area 1 (five test pits in 1990 and a block excavation of 10 adjacent 2 x 2 m pits in 1995) revealed a residential/administrative structure, containing at least three sequential clay floors, all dating to the Late Postclassic (Pollard and Cahue, 1999). Eighteen intact elite burials were excavated in the walls, floors and outside this structure (Figure 8). The grave goods associated with these burials include bronze artifacts, polychrome ceramic vessels, carved bone, spinning and weaving tools, knives and projectile points (Pollard, 2000, Pollard and Cahue, 1999). An underlying structure constructed of large adobe bricks has been dated to the Classic period (A.D. 300- 500), and is currently the earliest occupation at the site. No burials were associated with this structure (Pollard and Cahue, 1999).

Three test pits were excavated in area 2 in 1990 and a block excavation was partially excavated in 1995. There are no intact discrete burials from area 2. Artifactual and soil analyses indicate that area 2 represents three layers of cultural deposits (Pollard, 2000). First, a residential deposit (probably commoners) dating to the Middle Postclassic, which included the disarticulated human remains of two individuals (pollard and Cahue, 1999). Second, a residential deposit with a series of clay floors dating to the Late Postclassic; and third, a residential midden above a red clay floor dating to the sixteenth century (Pollard, 2000).

Area 5 consists of artificially terraced slopes separated by large retaining walls. In 1990, two test pits were excavated adjacent to two pyramid platforms located on a terrace. A block (10 x 6 m) was excavated in the terrace in 1994, incorporating one of the test pits in which part of a tomb was found. In the upper levels of all units there was a heavy representation of artifacts associated with Tarascan ritual and state religion (Pollard, 1993, Pollard and Cahue, 1999). Below a rock pavement, there is a secondary fill dating to the Early Postclassic (ca. A.D. 900 – 1000); and this fill oaverlays a primary deposit consisting of a series of sealed floors dating from the Late Classic to the Epi-Classic period (A.D. 500 – 900). Below the floors of the elite residential structure is a sealed stone-lined tomb from which eighty-seven grave goods and five burials (ten individuals) were recovered Pollard and Cahue, 1999).

The Urichu skeletal remains provide a temporal control for this study because they represent the only collection of intact, stratigraphically controlled and radiometrically dated burials in the Lake Pátzcuaro Basin (Pollard, 1995).

Thirty-three burials and several disarticulated and scattered remains were recovered, representing a minimal number of individuals of forty. In area 1(Figure 8), there were 19 burials (21 individuals), in area 2 there were only disarticulated scattered remains (2 individuals), and in Area 5 there were 14 burials (17 individuals). Of the burials in Area 5 (Figure 9), five were inside a tomb, and three were among the flat stones that formed the roof of the tomb. It is possible that two of these burials were deposited on the roof of the tomb. The other burials are inside walls, in flat-stone boxes, or directly on the bedrock.

The early (area 5) burials were in extended position, in tombs, flat-stone boxes, or in walls. The more recent (area 1) burials were in a flexed position, most on the right side. There are no observable patterns with regard to the orientation of the bodies. Four of the burials recovered from Area 1 during the season of 1995 were looted (B28, B29, B30 and B32) during excavations, and it is not known which was their exact position. Some of these burials had been partially excavated prior to disturbance, in these cases it was possible to determine the individual's approximate position. Looted burials were reconstructed in the laboratory, based on size of bones, side of the bones, and the color and state of preservation of the surface of the bone.

Preservation is varied, ranging from very poor to very good. The degrees of completeness of the burials are average to good, but the remains are mostly fragmented.

Complete inventories for each burial can be found in the final project report to INAH (Pollard, 2000).

Tócuaro (Rank 4 or 5)

The Tócuaro collection was excavated during the 1996 field season of the "Proyecto Carretera Pátzcuaro-Uruapan" of the Subdirección de Salvamento Arqeológico - INAH, under the direction of the archaeologist Salvador Pulido Méndez. A total of seven individuals were recovered (Pulido Mendez, personal communication). An accelerated mass spectrometry (AMS) date from bone places this site in the Late Postclassic (ca. A.D. 1425). The burials were incomplete and the preservation was generally poor. All burials were recovered from the fill of several structures (Figure 10).

Atoyac - Rank 4 or 5

The site of Atoyac was excavated as part of the "Proyecto Arqeológico de la Cuenca de Sayula" (PACS) (Acosta, 1996; Acosta et al., 1998). The site is located on the eastern lakeshore of Lake Sayula. Excavations were conducted as a salvage project in the neighborhood of San Juan in Atoyac, Jalisco. A total of one hundred and fourteen burials (MNI= 140) were recovered from four areas of the site: residential area, burial area 1, burial area 2, and burial area 3.

These areas were determined to be chronologically distinct. Based on Kelly's (1948) ceramic chronology, the residential area and burial areas 1 and 2 date to the Amacueca phase (A.D. 1100 – 1523), which corresponds to the Late Postclassic (A.D. 900 – 1523); burial area 3 dates to the Sayula phase (A.D. 600 – 1100) which corresponds to the Middle Classic – Early Postclassic (A.D. 500/600 – 1100) (Acosta et al., 1998). Isolated remains representing two individuals were also recovered and are dated to the Verdia phase (0 – A.D. 600) corresponding to the Late Preclassic – Early Classic (0 – A.D. 500/600) (Acosta et al., 1998).

The Verdia phase is not well represented in the Sayula Basin. The shaft tomb tradition begins to disappear during toward the end of this period. The absence of Verdia remains in the Basin may be due to settlement shifts secondary to economic and political restructuring of the basin (Acosta et al., 1998). The Sayula phase is characterized by marked population explosion as settlements grow in number and density. There is evidence for craft specialization (for example, salt extraction, ceramic production, architecture, shell workshops) (Acosta et al., 1998). The presence of monumental architecture and craft specialization suggest the presence of a complex social system (perhaps a chiefdom) capable of harnessing human labor and securing the exploitation and distribution of resources (Acosta et al., 1998). During the Amacueca phase there is a restructuring of settlement patterns coupled with population growth, new ceramic styles, and new techniques for salt extraction. All of these changes suggest s shift in economic and social systems. There is also a change in mortuary treatment, as evidenced by the type of grave goods. There is evidence for differential access to resources, and for ascribed elite status (Acosta et al., 1998).

Of the one hundred and fourteen burials, ninety-two are individual and twenty-two were multiple. There are thirty-two burials in area 2 (Sayula phase), thirty-three in area 3 (Amacueca phase), twenty-seven in area 1 (Amacueca phase) and 20 in the residential area (Amacueca phase (Acosta, 1996). Combining the areas, there are 32

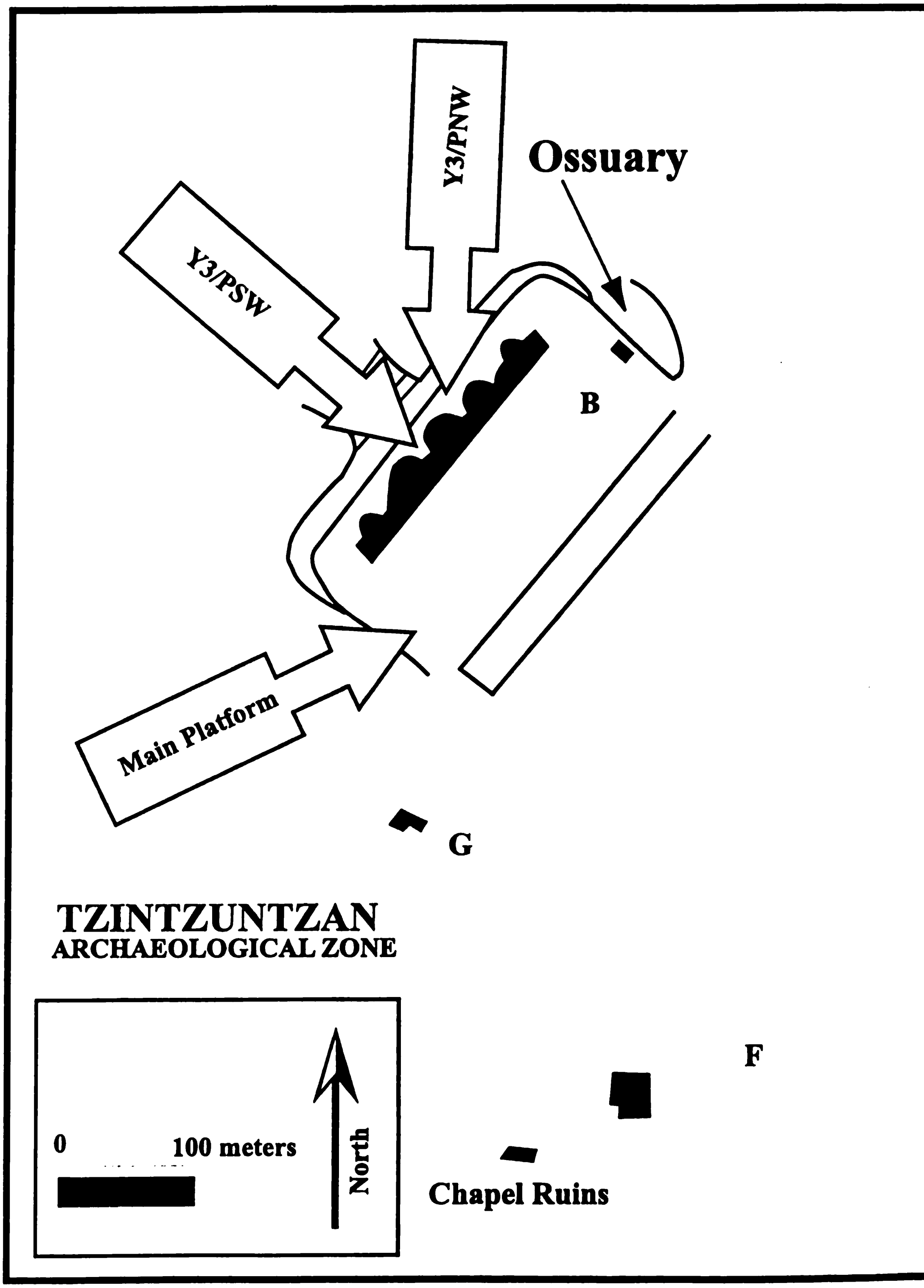

Figure 5. Main Platform in the archaeological zone of Tzintzuntzan and excavated structures. Most intact burials were excavated from block Y3/PNW (Modified from Pollard, 1993).

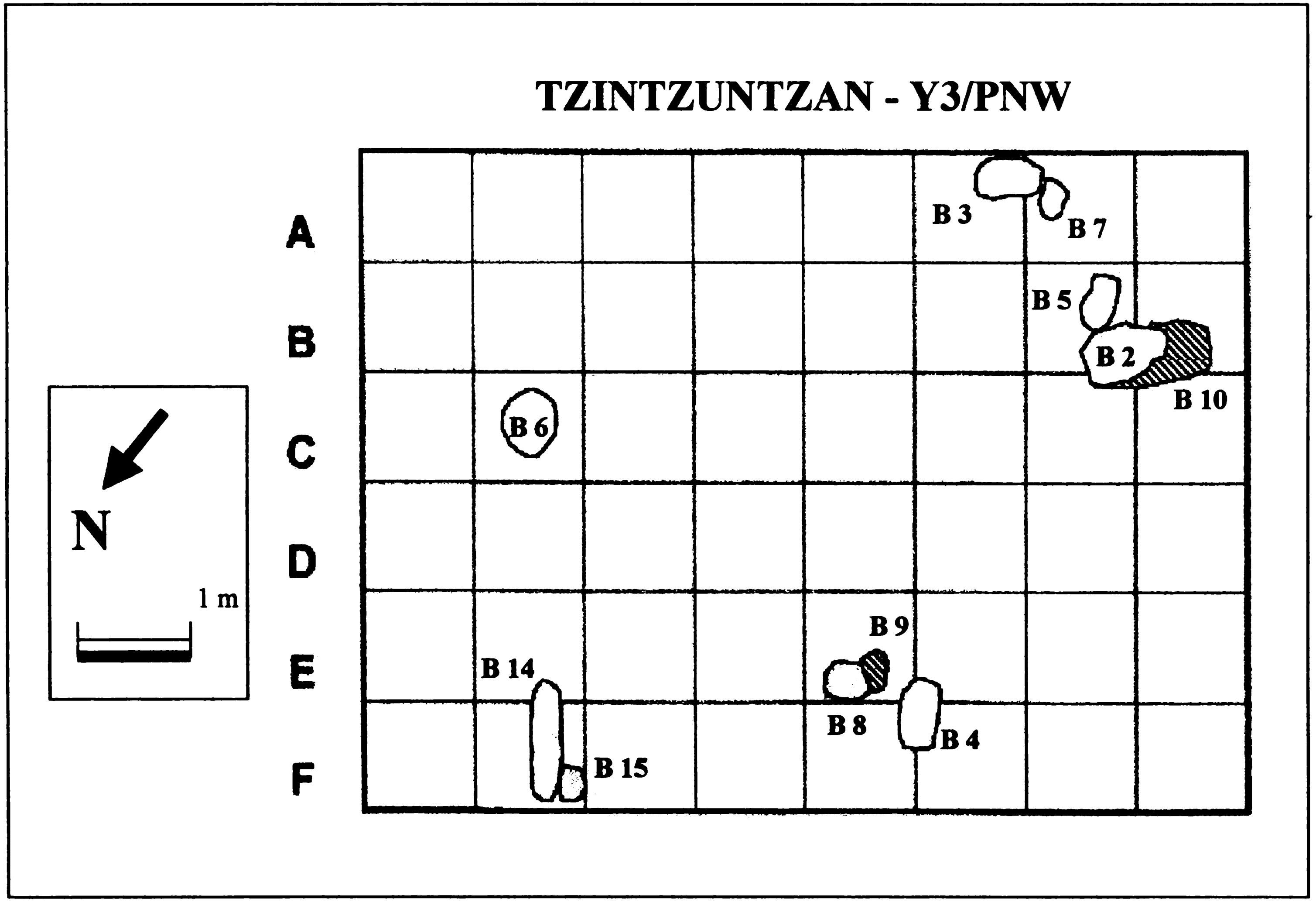

Figure 6. Excavation block 1 (Y3/PNW) with intact burials recovered during the 10th field season.

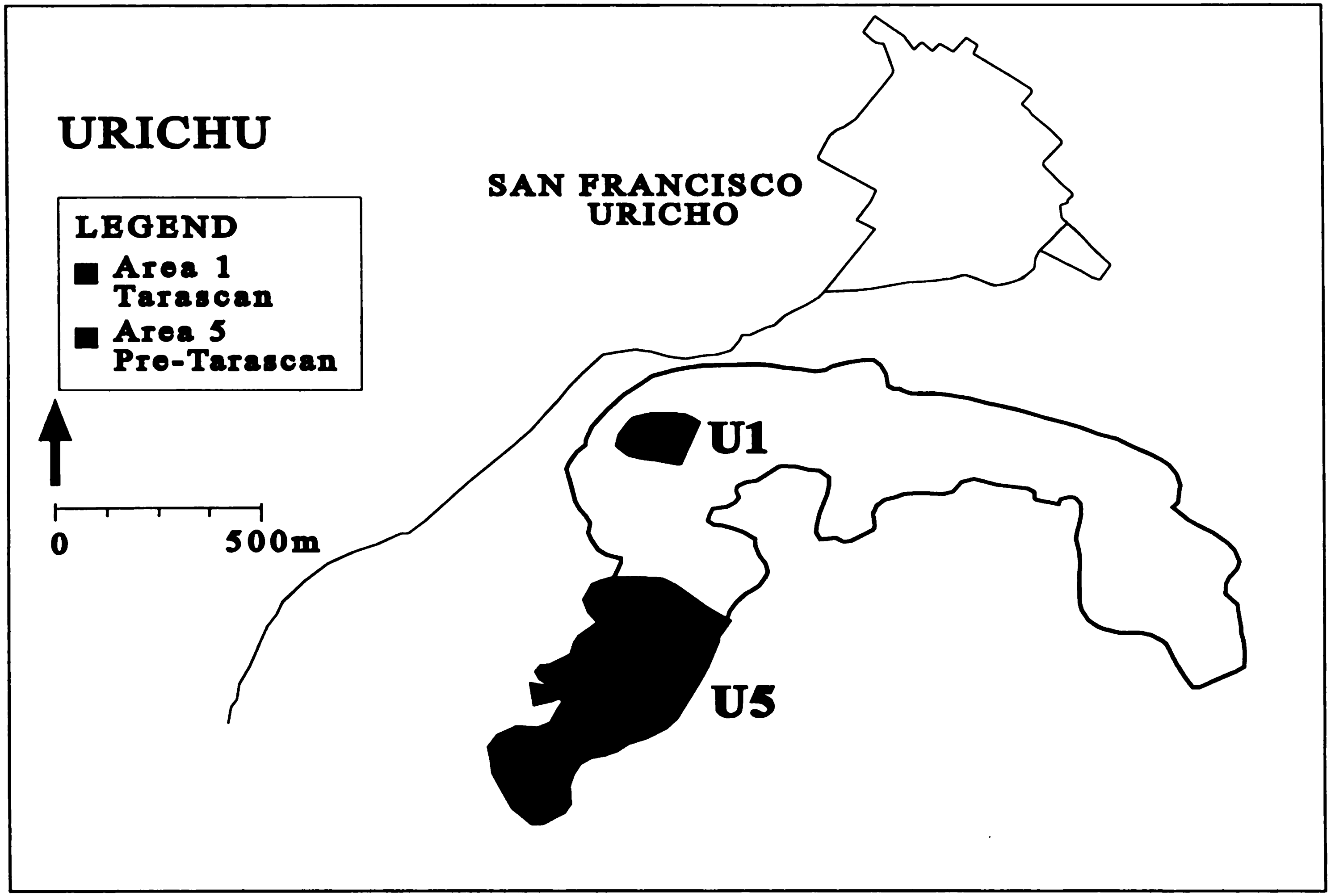

Figure 7. Map of the site of Urichu showing areas where the intact burials included in this study were recovered (modified from Pollard and Cahue, 1999).

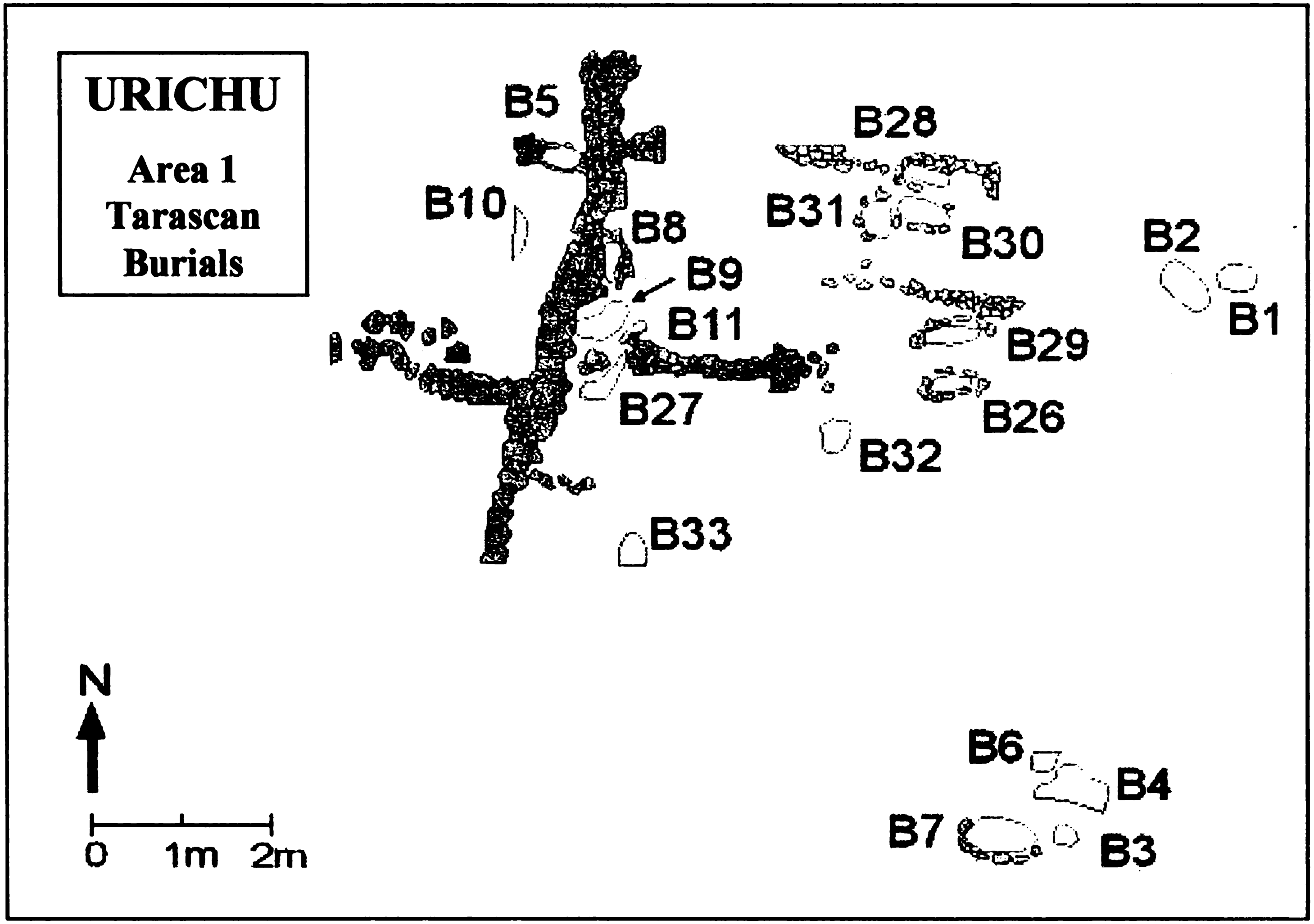

Figure 8. Map of Urichu, Area 1 showing location of burials (modified from Pollard and Cahue,1999).

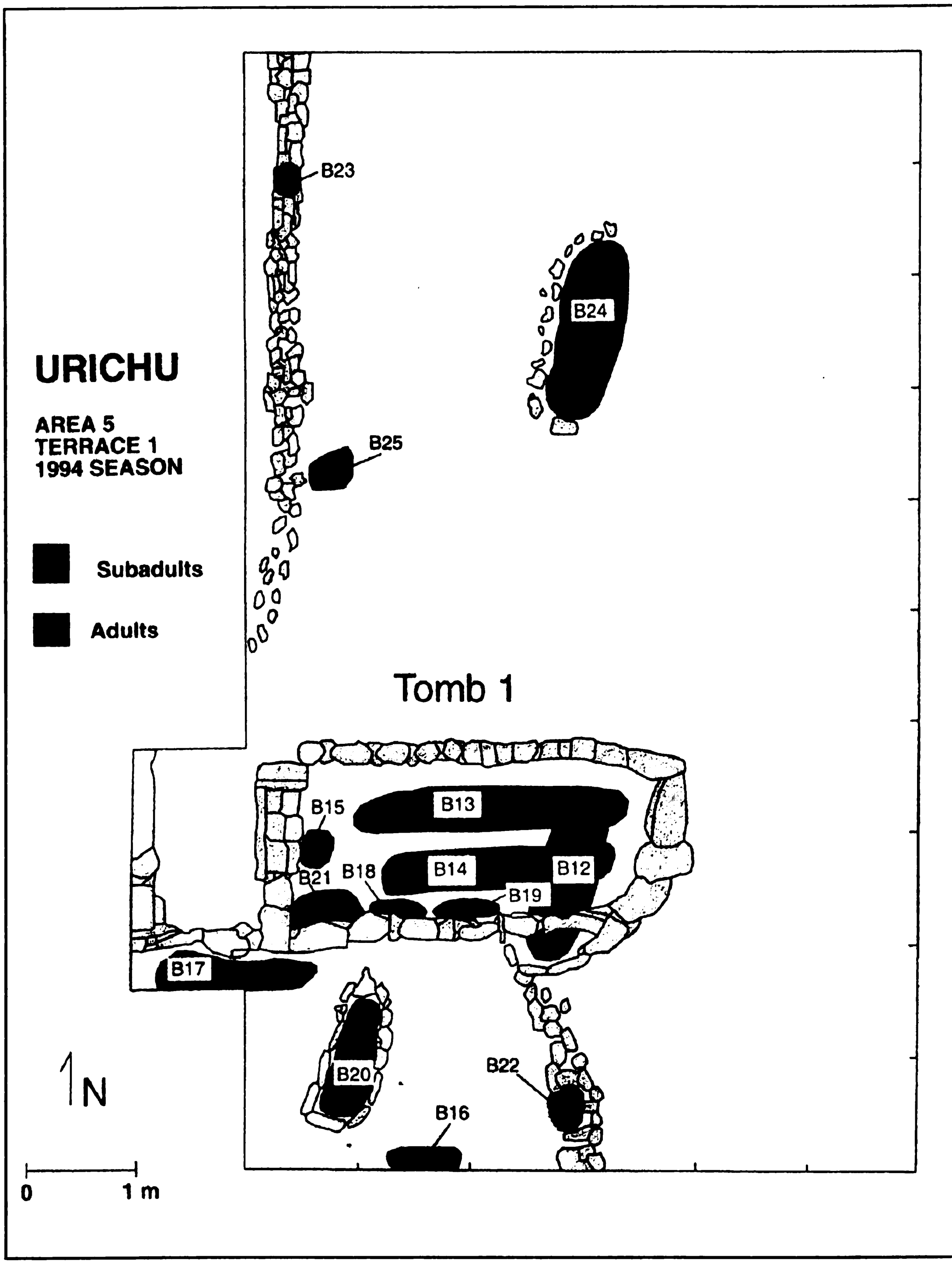

Figure 9. Map of Urichu, Area 5 showing the location of burials (modified from Pollard and Cahue, 1999).

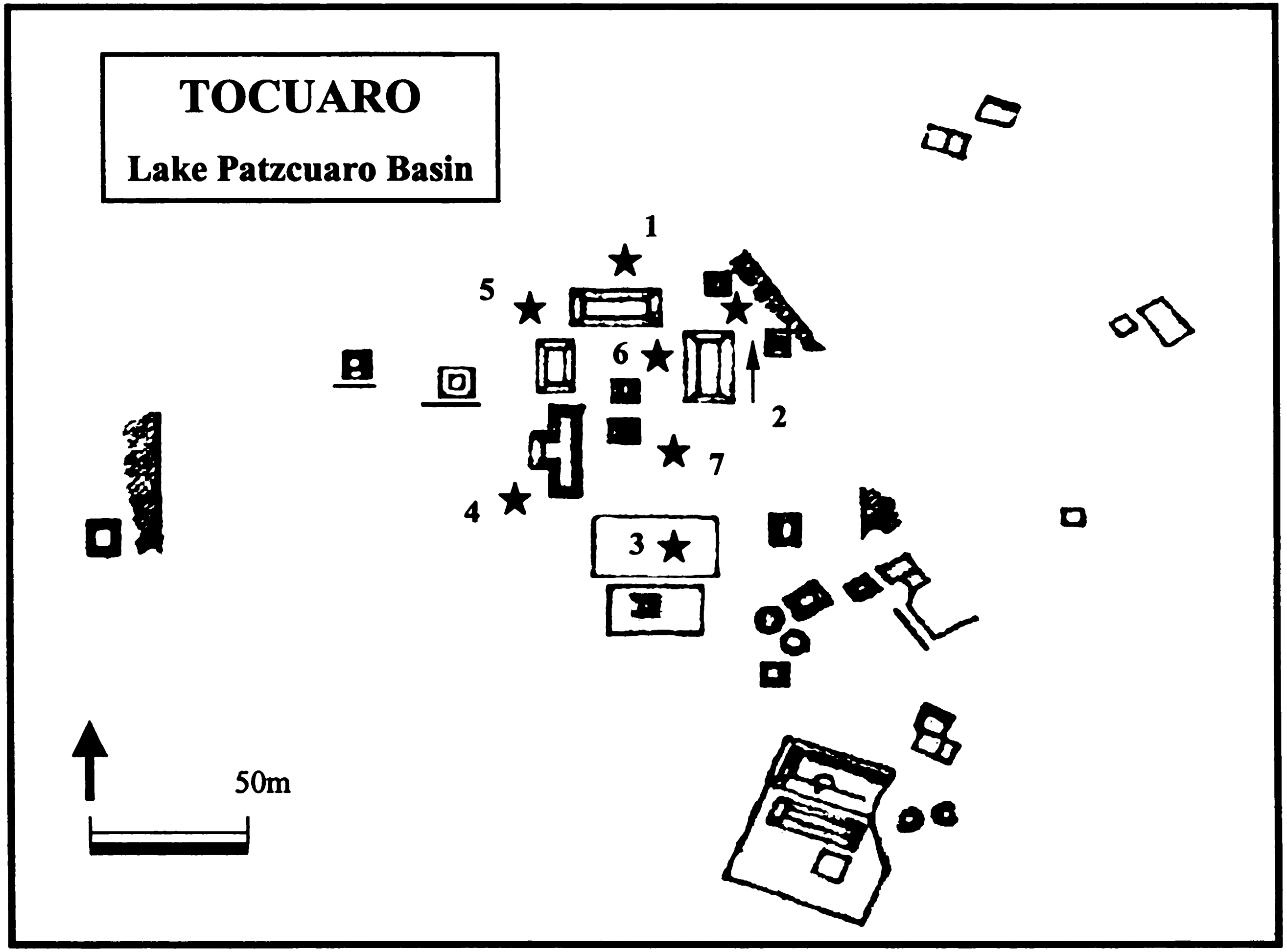

Figure 10. Tocuaro site. Burial area showing the location of burials included in the study (modified from Araiza and Dominguez with permission from Salvador Pulido, Salvamento Arqueologico, INAH).

burials in the Sayula phase (MNI = 45), and 80 burials in the Amacueca phase (MNI = 94) (Acosta, 1996).

Only twelve individuals in the Sayula phase have associated grave goods which include bead necklaces and bracelets, shell objects, figurines, and ceramic vessels typical of the Sayula ceramic style (Acosta, 1996). There is variation in the grave goods associated with the Amacueca phase burials. The residential area burials are associated with ceramic vessels, copper tweezers and needles, obsidian lip plugs, copper bells, stone beads, and shell bracelets (Acosta, 1996). Area 1 burials are associated with few grave goods, which include miniature vessels, obsidian lip plugs, copper wire and rings, and in one case, shell beads (Acosta, 1996). Area 3 burials are associated with Tarascan polychrome ceramics, and Amacueca style ceramics. Also included are copper bells and tweezers, obsidian lip plugs, and in fewer quantities, shell pendants (Acosta, 1996).

The collection was under study at the time of the pilot study, but 10 samples: five from the Sayula phase (area 2), and five from the Amacueca phase (area 3) were secured for inclusion in the study.

Sample Composition

Sixty-five individuals previously identified as elites (based on grave goods, spatial context, mortuary and ethnohistoric evidence) were selected for the study; only adults were included. Seventeen individuals were included in the Pre-Tarascan sample; 11 males and 5 females and 1 undetermined. The Tarascan sample is composed of 48 individuals; 27 are males and 17 females and 4 undetermined (Table A1).

Permission for extraction and export of samples from the collections housed in Mexico was obtained from the *Consejo de Arqueología*, and the *Dirección de Antropología Física, Instituto Nacional de Antropología e Historia* (INAH). Samples of five grams of bone were collected from skeletal elements that were the least diagnostic for anatomical or pathological study. Bones were sampled with a preference for already fragmented skeletal elements since the available evidence suggests that there is not difference in isotopic signature between skeletal elements in adults (Schwarcz and Schoeninger, 1991).

Faunal remains, representing dietary items, were sampled, and they include fish, rabbit, turkey, deer, peccary and dog.

Age and Sex Determinations

The fragmentary nature of many of these remains made the determination of age and sex difficult. The age and sex determinations of the human skeletal remains were assessed by Cahue at the end of each field season; all determinations were revised by L. Cahue and N. Sauer at the end of the 1996 season during Sauer's field supervisory visit. Age estimates were determined primarily by examination of the degree of wear on the molar teeth. Cahue and Sauer independently seriated all the dentition available and assigned the individuals to one of six age categories: subadult (0-12), adolescent (12-20), adult (20 +), young adult (20-35), middle adult (35-50), and older adult (50 +) (Buikstra and Ubelaker 1994). Of the 40 individuals examined, the observers agreed on age categories for 39 cases, and disagreed in one case where most of the teeth were missing. In cases where only long bones were available, the age was assigned as adult (20+).

The assignation of sex for this population proved to be a more complex problem. The method of choice for most physical anthropologists for the assessment of sex in the human skeleton is, without a doubt, Phenice's (1969) method (St. Hoyme and Iscan 1989). The Phenice method, based on morphologic indicators of sexual dimorphism in the hip bone, while reliable, is inappropriate for very fragmented remains where the necessary morphological features are unobservable, as is the case in most of the skeletal remains in the study (Pollard and Cahue, 1999). In addition to the difficulties inherent in sexing fragmented remains, this population is characterized by gracile postcrania with robust crania. This biological characteristic often led, in the preliminary stages of analysis, to conflicting sex assignations for the same individual, depending on which part of the skeleton was being scored (postcranium or cranium). This pattern appears to reflect the changes in sexually dimorphic features occurring with age. The morphology of both male and female skulls tends to become more "masculine" as individuals get older (White and Folkens, 1991; Meindl et al., 1985). Post-menopausal females develop more "masculine" cranial features while developing an increasingly gracile postcranium due to a greater susceptibility to age-related bone loss (Raisz, 1982; Walker, 1995). Males continue to develop their sexually dimorphic cranial traits until the age of thirty (Walker, 1995). Unrecognized, these age-related changes in sexually dimorphic features can be problematic, especially in poorly preserved, fragmentary and incomplete skeletal collections where there is a tendency for young males to be classified as females or in an undetermined category. Conversely, older females tend to be classified as males (Walker, 1995). These biases lead to erroneous demographic profiles (Weiss, 1972).

To overcome these biases all available skeletal collections were surveyed to assess the range of variation in sexually dimorphic features. Age was estimated before sex was assigned. The survey reveled that the mandible was the best represented across all the samples. A relatively new method for the assignation of sex in skeletal remains using the mandibular ramus flexure was applied. The sex assignations determined by this method were compared to those previously determined, and there was a one hundred percent agreement.

Scoring of the morphological indicator of sexual dimorphism in the mandibular ramus flexure (Loth and Henneberg 1996) was chosen because in most of the cases examined, the mandible was the best represented across the population, the feature was easily observed and scored, and it did not require an intact bone, thus, we were able to include fragmented mandibles.

In spite of the challenges posed by incomplete, fragmented and sometimes poorly preserved remains, two independent observers (Cahue and Sauer) agreed on the sex of all but two individuals in the Urichu sample.

For the Tzintzuntzan materials, samples were taken from crania wherever possible. In these cases, sex assignation was determined by analyzing sexually dimorphic features of the skull. The long bone samples were clearly labeled and were recovered from very distinct areas of the site, eliminating the possibility of sampling the same individuals represented by the crania. The Tzintzuntzan-ossuary sample was obtained by selecting left-sided fragmented mandibles.

HYPOTHESES

In order to evaluate the ability of elites to use their political and economic power to obtain maize from outside the Lake Pátzcuaro Basin, two sets of hypotheses regarding the isotopic composition of the bone collagen of elites in the Tarascan state were tested. One set evaluated temporal shifts in maize consumption, and another, the differences in maize consumption between administrative centers within the Tarascan state of different rank.

Temporal Shifts in Maize Consumption

This set of hypotheses is concerned with temporal shifts in the relative proportions of maize in the diet. Ethnohistoric sources indicate that maize was one of the principal items flowing into the Lake Pátzcuaro Basin as a tribute, indicating that maize was of economic value to the state. Evidence for the symbolic value of maize to the Tarascans can be found in its pervasive role in the language describing the anatomy, life cycle and harvesting seasons, as well as metaphoric references for birth, strength, and renewal of the society (Pollard, 1993). Given its nutritional, economic and symbolic value, it is very likely that the Tarascans would have used all means available to obtain this item. Therefore, this study postulates that the Tarascans used their political and economic power to obtain maize, maintaining its dietary level.

If the elite were indeed, able to obtain maize for their consumption needs, the $\delta^{13}C$ and $\delta^{15}N$ values from the bone collagen of Pre-Tarascan and Tarascan elites are expected to show no difference. A downward shift in $\delta^{13}C$ would indicate a decline in the relative proportion of maize in the diet. This could mean that 1) although maize flowed into the Pátzcuaro Basin the elite did not consume it, 2) the flow of maize into the

Basin was insufficient to offset supply deficits, or 3) the ethnohistoric record is inaccurate and the elite did not have enough power to obtain maize from outside the Basin.

An upward shift in $\delta^{13}C$ would indicate that not only did the elite have enough power to obtain maize, but also obtained enough to consume more of it. This, however, would be very unlikely since an increase in the amount of maize in the diet would result in a percentage of calories derived from maize higher than any reported (75%).

If the proportion of maize in the diet decreased it is possible that the population may have attempted to meet calorie-energy needs by consuming more meat. This scenario, however, is unlikely since the Basin's supply of terrestrial meat resources was also insufficient. In the hypothetical diet, less than 10% of the calories are derived from meat protein and fish combined. For meat to provide 25% of calories, an individual would have to reach a daily consumption of approximately 550g of meat and fish combined. Current estimates for meat availability would only be enough for 14g/day per person. An alternative would have been to increase the consumption of fish since it was produced at a surplus. Fish provides 67cals/100g; it would take more than 500g of fish to provide the same amount of calories in 100g of maize (358cal/100g). As shown in Chapter 3, even under the assumption of equal distribution of food resources, and the consumption of 100% of available resources (as estimated by Pollard, 1982), the available fish harvest would only be enough to provide 162g fish/day per person (80,000 population). Therefore, no changes in the relative proportion of meat consumed are expected.

> **NULL HYPOTHESIS I:** There is no significant difference in the mean $\delta^{13}C$ values of Pre-Tarascan and Tarascan elites within the Lake Pátzcuaro Basin.

ALTERNATIVE HYPOTHESIS I: There is a significant difference in the mean $\delta^{13}C$ values of Pre-Tarascan and Tarascan elites within the Lake Pátzcuaro Basin.

NULL HYPOTHESIS Ia: There is no significant difference in the mean $\delta^{15}N$ values of Pre-Tarascan and Tarascan elites within the Lake Pátzcuaro Basin.

ALTERNATIVE HYPOTHESIS Ia: There is a significant difference in the mean $\delta^{15}N$ values of Pre-Tarascan and Tarascan elites within the Lake Pátzcuaro Basin.

Ethnohistoric and archaeological data indicate that the site of Atoyac in the Sayula Basin was part of the Tarascan state's borderlands. The integration of this Basin into the state took place between A.D. 1440 and 1500. The high ratio of maize consumed/maize carried for one individual making the trip to Sayula indicate that Tarascan interest in the Sayula Basin was not maize. Tarascan interest in gold and silver, coupled with the lack of salt in the Lake Pátzcuaro Basin suggest that interest in the Sayula Basin was most likely related to their rich gold and silver mines and to their salt resources (Valdez and Liot, 1996). How did integration into the Tarascan State affect the diet of elites in the Sayula Basin?

Recall that the Tarascan elite in the Lake Pátzcuaro Basin exported elite culture and military service in return for tribute. Tarascan control of conquered settlements involved the presence of Tarascan elites from the geopolitical core, mainly from Tzintzuntzan as administrators. Atoyac was under the control of the Tarascan state, and it was located on the frontier margins of the state's territory, or ethic segregation zone. These settlements were populated by different ethnic communities. Local elites were selected and approved by the Tarascan king to administer their own communities. Tarascan elites from Tzintzuntzan were only in charge of small Tarascan communities

(Pollard, 1993). The Tarascan ambassadors would also insure the loyalty of all communities to the state. The local elites in the Sayula Basin would have been able to coerce labor from local populations, to work in the gold and silver mines, produce salt for tribute and to maintain the production of maize for their consumption.

Dietary signals of bone collagen are set for life by adulthood. With a very slow bone turnover rate (20 years), they vary very little throughout the life of an individual (Stenhouse and Baxter, 1979). Therefore, it is possible to identify individuals whose early-life diets were different from those of the local population. If the Tarascan Amacueca burials represent local individuals who acquired the Tarascan ethnic identity, their diets should be the same as the Pre-Tarascan Sayula sample. If they were Tarascan elites sent from the capital of Tzinztuntzan, their diets should be the same as that of Elites from Tzintzuntzan.

NULL HYPOTHESIS II: There is no significant difference in the mean $\delta^{13}C$ values of Pre-Tarascan and Tarascan elites at Atoyac in the Sayula Basin.

ALTERNATIVE HYPOTHESIS II: There is a significant difference in the mean $\delta^{13}C$ values of Pre-Tarascan and Tarascan elites at Atoyac in the Sayula Basin.

NULL HYPOTHESIS IIa: There is no significant difference in the mean $\delta^{15}N$ values of Pre-Tarascan and Tarascan elites at Atoyac in the Sayula Basin.

ALTERNATIVE HYPOTHESIS IIa: There is a significant difference in the mean $\delta^{15}N$ values of Pre-Tarascan and Tarascan elites at Atoyac in the Sayula Basin.

Dietary Differences between Administrative Centers of Different Rank

Within the Tarascan core, the distribution of resources to elites may have been uneven, and determined by the rank of the settlements they administered. Given the symbolic and nutritional importance of maize in the Lake Pátzcuaro Basin (as it was in the rest of Mesoamerica), it is unlikely that elites would have tolerated reduced levels of maize consumption. Thus, no differences between settlements in the proportion of maize consumed are expected.

A decrease in the $\delta^{13}C$ of Rank 3 and Rank 4/5 centers compared to Tzintzuntzan (Rank 1 and Rank 2) would indicate that administrative elites were not consuming the same amount of maize as the Tarascan royal family and nobility. This could be due to uneven distribution of resources from Tzintzuntzan. It could also reflect the amount of lacustrine, fertile lands under the control of the administrative centers, and their population densities (Pollard, 1993). Elites at centers with less fertile land and higher population densities may have been successful enough to prevent temporal shifts in diet, but not as successful as other centers with more fertile land and less people.

An upward shift in $\delta^{13}C$ could reflect a form of "silent resistance." to the political and economic control from Tzintzuntzan. Local elites could have rebelled to state control by hiding or hoarding maize, and "unofficially" consuming more maize than the nobility at Tzintzuntzan. The severe punishments for such activities recorded in the ethnohistoric records suggest that it may have been a problem for the state.

> **NULL HYPOTHESIS III:** There is no significant difference in the mean $\delta^{13}C$ values of elites at Tzintzuntzan and lower administrative centers (Urichu and Tócuaro).
>
> **ALTERNATIVE HYPOTHESIS III:** There is a significant difference in the mean $\delta^{13}C$ values of Tzintzuntzan and lower administrative centers (Urichu and Tócuaro).
>
> **NULL HYPOTHESIS IIIa:** There is no significant difference in the mean $\delta^{15}N$ values of Tzintzuntzan and lower administrative centers (Urichu and Tócuaro).

ALTERNATIVE HYPOTHESIS IIIa: There is a significant difference in the mean $\delta^{15}N$ values of Tzintzuntzan and lower administrative centers (Urichu and Tócuaro).

The ossuary at the capital city of Tzintzuntzan may contain the remains of war victims, or individuals who served the royal family and nobility. Whether those victims were captured warriors later sacrificed, or Tarascan warriors killed during war, is not clear. Males engaged in warfare would have consumed a greater proportion of meat than the rest of the population (Pollard, 1993).

If the ossuary remains represent Tarascan warriors, the $\delta^{13}C$ values in bone collagen from individuals in the ossuary are expected to be the same as those from the Tarascan nobility at Tzintzuntzan. If these remains represent servants, the $\delta^{13}C$ values in bone collagen from individuals in the ossuary are expected to be lower than those from the Tarascan nobility at Tzintzuntzan.

If the ossuary remains represent captured warriors, their isotopic values should reflect the elite diets of their settlements, for example Aztec.

The $\delta^{15}N$ values of the Tzintzuntzan-Ossuary individuals is not expected to differ from the Tzintzuntzan nobility. An upward shift in $\delta^{15}N$ may indicate the army members consumed a better quality diet, while a downward shift would suggest that since members of the army were drawn from elite centers throughout the state, their diets would reflect be similar to the diet of other elites in the state.

NULL HYPOTHESIS IV: There is no significant difference in the mean $\delta^{13}C$ values of Tzintzuntzan elites and the individuals from the Tzintzuntzan ossuary.

ALTERNATIVE HYPOTHESIS IV: There is a significant difference in the mean $\delta^{13}C$ values of Tzintzuntzan elites and the individuals from the Tzintzuntzan ossuary

NULL HYPOTHESIS IVa: There is no significant difference in the mean $\delta^{15}N$ values of Tzintzuntzan elites and the individuals from the Tzintzuntzan ossuary.

ALTERNATIVE HYPOTHESIS IVa: There is a significant difference in the mean $\delta^{15}N$ values of Tzintzuntzan elites and the individuals from the Tzintzuntzan ossuary.

METHODS

Sample Preparation

All samples were mechanically cleaned with a brush and a Dremel tool to remove the outer layer of bone. Clean bone pieces were rinsed in a 0.01 M HCl solution for 10 seconds, and immediately rinsed in cold (4°C) deionized water to neutrality. The samples were then air dried under a hood at room temperature, for 48 hours.

The organic matter ("collagen") was extracted from bone fragments by slow demineralization (Moore et al., 1989; Sealy, 1986). Approximately 0.5g of clean, dry bone were soaked in 50 ml of a 0.25 M HCl solution for two weeks, and checked every three days for translucency as an indicator of complete demineralization. The acid solution was changed every five days to maintain the concentration gradient. The demineralized fragments were rinsed to neutrality, and soaked in 0.125 M NaOH for 20 hours, rinsed to neutrality again, and dried under vacuum at 55°C for 24 hours. Dry samples were weighed and stored in combusted glass vials.

Analysis of Extracted Organic Matter ("collagen")

Between 0.4g and 0.6g of dry sample were weighed into tin sample cups, and placed in an automated sampler tray. An internal standard (sulphanilamide) was weighed every 10 samples. The samples were flash combusted in a Carlo Erba elemental analyzer attached to a Finnigan MAT Delta Plus mass spectrometer.

Each sampled was prepared for combustion twice: once for a measure of $\delta^{13}C$, and a second time for a dual measure of $\delta^{13}C$ and $\delta^{15}N$ to obtain data for carbon to nitrogen ratio (C/N) calculations. Replicate samples were prepared and measured for a randomly selected sub-sample. Carbon to nitrogen ratios were evaluated and compared to collagen extraction yields to evaluate the integrity of the organic material.

Statistical Analysis

Choosing the appropriate statistical test in any scientific study is of paramount importance. The choice of which test to use depends on the type of data, the shape of the population from which samples are drawn, the size of the samples, whether samples are paired (matched) or independent, and the standard deviation of the populations form which the samples were drawn (Edmondson and Druce, 1996). In addition, the direction of the alternative hypothesis must also be considered.

Parametric statistical tests make assumptions about these parameters. The validity of these assumptions determines the meaningfulness of parametric tests (Siegel, 1956). A requirement of parametric tests is that scores be measured at least at an interval ratio level, that the shape of the populations be that of a normal distribution (bell shape), and that the samples drawn be large. For the purpose of this study, sample sizes are defined as: large (above 30); small (20 to 30); and very small (less than 20) (Edmondson and Druce, 1996).

Nonparametric statistical tests do not specify conditions about the population from which the sample was drawn. The assumptions made by nonparametric tests are that the observations are independent and the variable under study is continuous. The strength of measurements required for nonparametric tests is not as strong as that required by parametric tests. Nonparametric tests require only that data be in at least an ordinal scale.

Although the observations in this study are measured at an interval scale, the data fail to meet most of the assumptions of parametric statistical tests. The shape of the population is unknown, the sample sizes are very small, and the standard deviation of the population is unknown. For these reasons, the nonparametric Mann-Whitney U test will be used to test differences between two independent samples. This test is one of the most powerful nonparametric tests, and it is the best alternative to the *t*-test, when parametric assumptions cannot be met (Siegel, 1956).

The computation of the test statistic, U is based on the ranks of the values rather than the values themselves. For an excellent step-by-step explanation, see Edmondson and Druce (1996). When one of the sample sizes is larger than 20 values the sampling distribution of U rapidly approaches the normal distribution. When this happens, a normal approximation of the U test is computed (Siegel, 1956). This study uses both calculations, and Tables B1 and B2 provide examples of their calculation and formulas.

All of the tests in this study are two-tailed and were conducted at a 5% level of significance ($\alpha = 0.05$); results are not significant for $p > 0.05$. The Mann-Whitney U tests were used to statistically test the hypotheses presented

In summary, two pooled samples were formed from various skeletal collections in the region. One samples is Pre-Tarascan (A.D. 1 – 1300) and another is Tarascan (A.D. 1300 – 1525). Two sets of hypotheses were formulated to test the ability of the Tarascan elites to obtain maize form elsewhere. These hypotheses test for diachronic and synchronic differences in relative proportions of maize in the diet. The samples available for study were very small, not permitting parametric statistical testing, therefore, this study used nonparametric statistical tests (Mann-Whitney U Test). The descriptions of the data, summary statistics and results of the tests are presented in the next chapter.

Chapter 5

RESULTS

The extraction yields, C/N values, and stable isotope ratios obtained for each of the sixty-five specimens are listed in Table C1. The overall precision (extraction and analysis) of the isotope analysis was $\pm$ 0.1. The extraction yields (yields of extracted protein) and carbon to nitrogen ratios of extracted proteins were measured during sample preparation to assess reliability of the stable isotope ratios. Nineteen randomly selected samples were analyzed several times to examine the reproducibility of the stable isotope ratios (see Table C2). The measured standard deviations ranged from 0.01 to 0.3, indicating good reproducibility.

Three of the samples analyzed were rejected as unreliable: samples URI-T-9.1 and TOC-T-7 are juveniles, and TOC-T-3.2 had a high C/N value. These samples are not used in subsequent discussions.

The extraction yields ranged from 1.57% (SAY-PT-35.1) indicating poor preservation, to 23.62% (TZN-T-13), characteristic of very well preserved bone. Recommended cutoff limits for extraction yields range from 1% (Schoeninger and Moore, 1992) to 5% (Schoeninger et al., 1989; Stafford et al, 1991). This study will follow the recommendations of Schoeninger and Moore (1992). All values are above the recommended cutoff point of organic residue > 1% of original dry bone weight. The C/N values ranged from 3.15 to 3.83 (TOC-T-3.2). All except one value (3.83) were within the acceptable range (2.7 – 3.6) recommended by Schoeninger and Moore (1992). Figure 11 shows that the C/N values are less variable (3.33 $\pm$ 0.13, expressed as the mean $\pm$ one standard deviation) than yield values (mean is 11.18% ± 4.77), indicating no relation between C/N and extraction yields (r = 0.335).

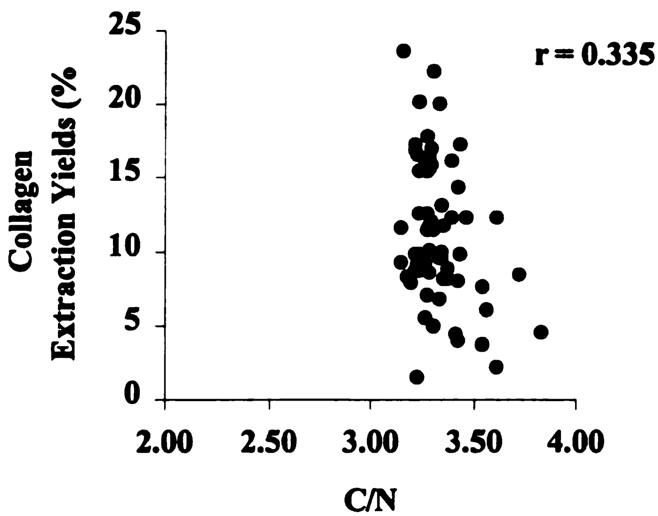

Figure 11. Collagen extraction yields and C/N values for all treated samples in the study.

The $\delta^{13}C$ and $\delta^{15}N$ values for the sixty-two specimens that produced reliable stable isotope ratios are listed in Table C1. The $\delta^{13}C$ values range from -14.6‰ to -10.8‰, and the $\delta^{15}N$ values range from 7.1‰ to 12.0‰. The lowest $\delta^{13}C$ value is from a Tzintzuntzan female, and the highest is from a male in the Sayula sample. The lowest $\delta^{15}N$ value is from the Area 2 female (URI-T-34) in the Urichu-T sample, and the highest $\delta^{15}N$ value is from a female in the Tzintzuntzan sample. Table 3 shows summary

TABLE 4

Mean $\delta^{13}C_{coll}$, and $\delta^{15}N_{coll}$ for Males and Females in Pre-Tarascan and Tarascan Sites

	$\delta^{13}C$ (‰)		$\delta^{15}N$ (‰)	
	Mean	**S.D.**	**Mean**	**S.D.**
TARASCAN	**-12.3**	**0.8**	**9.3**	**0.8**
Urichu				
Males (n = 10)	-11.7	0.6	8.8	0.5
Females (n = 6)	-12.2	0.4	9.0	0.7
Total (n = 16)	-11.8	0.5	8.9	0.6
Tocuaro				
Males (n = 3)	-13.2	0.8	9.0	0.8
Females (n = 2)	-13.3	0.2	8.5	0.3
Undetermined (n = 1)	-13.3	0.0	8.7	0.0
Total (n = 6)	-13.4	0.2	8.8	0.6
Tzint-Ossuary				
Males (n = 2)	-12.6	0.2	9.2	0.2
Females (n = 3)	-12.2	0.5	8.7	0.9
Total (n = 5)	-12.4	0.4	8.8	0.7
Atoyac-Amacueca				
Males (n = 5)	-12.1	0.4	9.8	0.6
Females (n = 0)				
Total (n = 5)	-12.1	0.4	9.8	0.6
Tzintzuntzan				
Males (n = 7)	-12.3	0.6	9.7	0.4
Females (n = 6)	-12.4	1.2	10.1	1.2
Total (n = 13)	-12.4	0.9	9.9	0.8
PRE-TARASCAN	**-12.2**	**0.7**	**9.4**	**0.8**
Urichu				
Males (n = 6)	-12.4	0.5	9.3	0.6
Females (n = 5)	-12.2	0.7	8.8	1.0
Undetermined (n = 1)	-12.4	0.0	9.3	0.0
Total (n = 12)	-12.3	0.6	9.1	0.8
Atoyac-Sayula				
Males (n = 5)	-11.9	0.9	10.0	0.3
Females (n = 0)				
Total (n = 5)	-11.9	0.9	10.0	0.3

statistics for the reliable stable isotope ratios from each site.

$\delta^{13}C$ in Pre-Tarascan Samples

The mean $\delta^{13}C$ value for the Sayula sample (n=5) is more positive (-11.9 $\pm$ 0.9) compared with the Urichu-PT sample (n=12) (-12.3 $\pm$ 0.6). This difference could be a reflection of sex composition of the sample, since the Sayula sample does not include females. A comparison between males shows a slight difference in means. The pooled Pre-Tarascan sample (n=17) has a mean $\delta^{13}C$ value of -12.2 $\pm$ 0.7.

$\delta^{13}C$ *in Tarascan Samples*

Among the Tarascan sites, the Tócuaro sample (n=6) produced the lowest mean $\delta^{13}C$ value with the lowest standard deviation (-13.4 $\pm$ 0.2) compared with the other sites. Of the remaining sites, Urichu-T (n=16) produced the highest (less negative) mean $\delta^{13}C$ value (-11.8 $\pm$ 0.5).

The difference in $\delta^{13}C$ values between the Amacueca (n=5) (-12.1 $\pm$ 0.4), Tzintzuntzan (n=13) (-12.4 $\pm$ 0.9), and Tzintzuntzan-Ossuary (n=5) (-12.4 $\pm$ 0.4) samples is small. Urichu-T (n=16) has a $\delta^{13}C$ value (-11.8 $\pm$ 0.5) that is 0.3‰ and 0.6‰ higher than Amacueca and Tzintzuntzan and Tzintzuntzan-Ossuary respectively. Within the Tzintzuntzan sample females show greater variation in $\delta^{13}C$ values (s.d. = 1.2) than males (s.d. = 0.6).

The pooled Tarascan sample (n=45) has a mean $\delta^{13}C$ value of -12.3 $\pm$ 0.8. The mean $\delta^{13}C$ value for pooled Tarascan males (n=27) is (-12.1 $\pm$ 0.7) and for Tarascan females (n=16) it is (-12.4 $\pm$ 0.8).

$\delta^{15}N$ in Pre-Tarascan Samples

The mean $\delta^{15}N$ value for the Sayula sample from Atoyac is higher (10.0 $\pm$ 0.3) than that for the Urichu-PT sample (n=12) (9.1 $\pm$ 0.8). A comparison among males alone also shows that the Sayula males (n=5) have a higher mean $\delta^{15}N$ value (10.0 $\pm$ 0.3) than the Urichu-PT males (9.3 $\pm$ 0.6). The pooled Pre-Tarascan mean $\delta^{15}N$ value is 9.4 $\pm$ 0.8.

$\delta^{15}N$ *in Tarascan Samples*

The mean $\delta^{15}N$ values for the Tarascan samples range from 8.8‰ to 10.0‰. The Tzintzuntzan sample (n=13) (9.9 $\pm$ 0.8) and the Amacueca sample (n=5) from Atoyac (9.8 $\pm$ 0.6) have the highest $\delta^{15}N$ values. Within the Lake Pátzcuaro Basin, the Urichu-T (n=16) (8.9 $\pm$ 0.6), Tócuaro (n=6) (8.8 $\pm$ 0.6) and the Tzintzuntzan-Ossuary (n=5) (8.8 $\pm$ 0.7) samples have mean $\delta^{15}N$ values similar to one another, but, on average, 1.0‰ lower than Tzintzuntzan (n=13) (9.9 $\pm$ 0.8) and Amacueca (n=5) (9.8 $\pm$ 0.6). The pooled Tarascan (n=45) mean $\delta^{15}N$ value is 9.3 $\pm$ 0.8. For males (n=27), the mean value is 9.3 $\pm$ 0.7, and for females (n=17) it is 9.2 $\pm$ 1.1.

Statistical Tests

Differences in the mean $\delta^{13}C$ and $\delta^{15}N$ values were tested with the Mann-Whitney U statistical test. Tables B3 and B4 summarize the results of the tests. Following is an examination of each null hypothesis with the Mann-Whitney U statistic.

> **NULL HYPOTHESIS I:** There is no significant difference in the mean $\delta^{13}C$ values of Pre-Tarascan and Tarascan elites within the Lake Pátzcuaro Basin.

The Mann-Whitney U test for differences in mean $\delta^{13}C$ values between the pooled Pre-Tarascan (-12.2 $\pm$ 0.7) and Tarascan (-12.3 $\pm$ 0.8) samples shows that there is not enough evidence to reject the null hypothesis ($Z_{crit} > Z_U$; $p>0.5$). Thus, no significant difference between the two groups was detected.

NULL HYPOTHESIS Ia: There is no significant difference in the mean $\delta^{15}N$ values of Pre-Tarascan and Tarascan elites within the Lake Pátzcuaro Basin.

The Mann-Whitney U test for differences in mean $\delta^{15}N$ values between the pooled Pre-Tarascan (9.4 $\pm$ 0.8) and Tarascan (9.3 $\pm$ 0.8) samples shows that there is not enough evidence to reject the null hypothesis ($Z_{crit} > Z_U$; $p>0.5$). Thus, no significant difference between the two groups was detected.

NULL HYPOTHESIS II: There is no significant difference in the mean $\delta^{13}C$ values of Pre-Tarascan and Tarascan elites within the Sayula Basin.

The Mann-Whitney U test for differences in mean $\delta^{13}C$ values between the Pre-Tarascan (Sayula) (-11.9 $\pm$ 0.9) and Tarascan (Amacueca) (-12.1 $\pm$ 0.4) samples from the Sayula Basin (Atoyac) shows that there is not enough evidence to reject the null hypothesis ($U'>U>U_{crit}$; $p>0.5$). Thus, no significant difference between the two groups was detected.

NULL HYPOTHESIS IIa: There is no significant difference in the mean $\delta^{15}N$ values of Pre-Tarascan and Tarascan elites within the Sayula Basin.

The Mann-Whitney U test for differences in mean $\delta^{15}N$ values between the Pre-Tarascan (Sayula) (10.0 $\pm$ 0.3) and Tarascan (Amacueca) (9.8 $\pm$ 0.6) samples from the Sayula Basin (Atoyac) show that there is not enough evidence to reject the null hypothesis ($U>U'>U_{crit}$; $p>0.5$). Thus, no significant difference between the two groups was detected.

NULL HYPOTHESIS III: There is no significant difference in the mean $\delta^{13}C$ values of elites at Tzintzuntzan and lower administrative centers (Urichu and Tócuaro).

The Mann-Whitney U test for differences in the mean $\delta^{13}C$ values between the Tzintzuntzan (-12.4 ± 0.9) and Urichu-T (-11.8 ± 0.5) samples shows that there is not enough evidence to reject the null hypothesis ($U>U'>U_{crit}$; $p>0.5$). Thus, there is no significant difference between the two groups.

The Mann-Whitney U test for differences in the mean $\delta^{13}C$ values between the Tzintzuntzan (-12.4 ± 0.9) and Tócuaro (-13.4 ± 0.2) samples shows that there is enough evidence to reject the null hypothesis ($U>U_{crit}>U'$; $p>0.5$). Thus, there is a significant difference between the two groups.

The Mann-Whitney U test for differences in the mean $\delta^{13}C$ values between the Tócuaro (-13.4 ± 0.2) and Urichu-T (-11.8 ± 0.5) samples shows that there is enough evidence to reject the null hypothesis ($U>U_{crit}>U'$; $p>0.5$). Thus, there is a significant difference between the two groups.

NULL HYPOTHESIS IIIa: There is no significant difference in the mean $\delta^{15}N$ values of elites at Tzintzuntzan and lower administrative centers (Urichu and Tócuaro).

The Mann-Whitney U test for differences in the mean $\delta^{15}N$ values between the Tzintzuntzan (9.9 ± 0.8) and Urichu-T (8.9 ± 0.6) samples shows that there is enough evidence to reject the null hypothesis ($U' > U_{crit} > U$; $p > 0.5$). Thus, there is a significant difference between the two groups.

The Mann-Whitney U test for differences in the mean $\delta^{15}N$ values between the Tzintzuntzan (9.9 $\pm$ 0.8) and Tócuaro (8.8 $\pm$ 0.6) samples shows that there is enough evidence to reject the null hypothesis ($U > U_{crit} > U'$; $p > 0.5$). Thus, there is a significant difference between the two groups.

The Mann-Whitney U test for differences in the mean $\delta^{15}N$ values between the Tócuaro (8.8 $\pm$ 0.6) and Urichu-T (8.9 $\pm$ 0.6) samples shows that there is not enough evidence to reject the null hypothesis ($U > U' > U_{crit}$; $p > 0.5$). Thus, there is no significant difference between the two groups.

> **NULL HYPOTHESIS IV:** There is no significant difference in the mean $\delta^{13}C$ values of Tzintzuntzan elites and the individuals from the Tzintzuntzan ossuary.

The Mann-Whitney U test for differences in the mean $\delta^{13}C$ values between the Tzintzuntzan (-12.4 $\pm$ 0.9) and Tzintzuntzan-Ossuary (-12.4 $\pm$ 0.4) samples shows that there is enough evidence to reject the null hypothesis ($U > U_{crit} > U'$; $p > 0.5$). Thus, there is a significant difference between the two groups.

> **NULL HYPOTHESIS IVa:** There is no significant difference in the mean $\delta^{15}N$ values of Tzintzuntzan elites and the individuals from the Tzintzuntzan ossuary.

The Mann-Whitney U test for differences in the mean $\delta^{15}N$ values between the Tzintzuntzan (9.9 $\pm$ 0.8) and Tzintzuntzan-Ossuary (8.8 $\pm$ 0.7) samples shows that there is enough evidence to reject the null hypothesis ($U > U_{crit} > U'$; $p > 0.5$). Thus, there is a significant difference between the two groups.

In summary, the data from the pooled Pre-Tarascan and Tarascan samples support the hypothesis that the proportion of maize in the diet of elites did not change over time. The Mann Whitney U test shows that the differences between the two groups is not significant. When examining the Lake Pátzcuaro and Lake Sayula basins independently, the data also indicate that there was no significant temporal change in the diet of elites.

The data examining differences between Tarascan administrative centers of different rank shows that the $\delta^{13}C$ of elites at Tócuaro was significantly lower than that all other sites in the study. The $\delta^{15}N$ data shows that mean values were significantly different between Tócuaro and Tzinztuntzan, but not significantly different from that at Urichu. The Amacueca individuals had a mean $\delta^{15}N$ similar to that of Tzintzuntzan, and the mean $\delta^{15}N$ value from the Tzintzuntzan-ossuary was similar to the Tócuaro and Urichu values.

Chapter 6

DISCUSSION, CONCLUSIONS AND FUTURE RESEARCH

The ability of elites to utilize economic power to obtain maize during the development of the Tarascan state was tested by examining two sets of hypotheses. The hypotheses were concerned with temporal shifts in diet and with dietary differences between elites from differently ranked administrative centers.

Temporal Shifts

The absence of a temporal shift in mean $\delta^{13}C$ and $\delta^{15}N$ values for the pooled Pre-Tarascan and Tarascan samples support the hypothesis that Tarascan elites were able to obtain enough maize to meet their dietary needs when the production of maize in Lake Pátzcuaro Basin was insufficient to support the population (Figure 12).

Disaggregating the data and examining differences between sites and between differently-ranked administrative centers provides more insight on the way resources were utilized within the state's structure. The mean $\delta^{13}C$ and $\delta^{15}N$ values for each site are presented in a bivariate plot (Figure 13). The plot shows that unlike elites at administrative centers within the Lake Pátzcuaro Basin, the elites at Atoyac (Sayula and Amacueca phases, alike) had a diet very similar to that consumed by the elites at Tzintzuntzan

The Sayula Basin incorporated into the state after A.D. 1440. The process of state expansion resulted in the incorporation of increasingly diverse communities. This

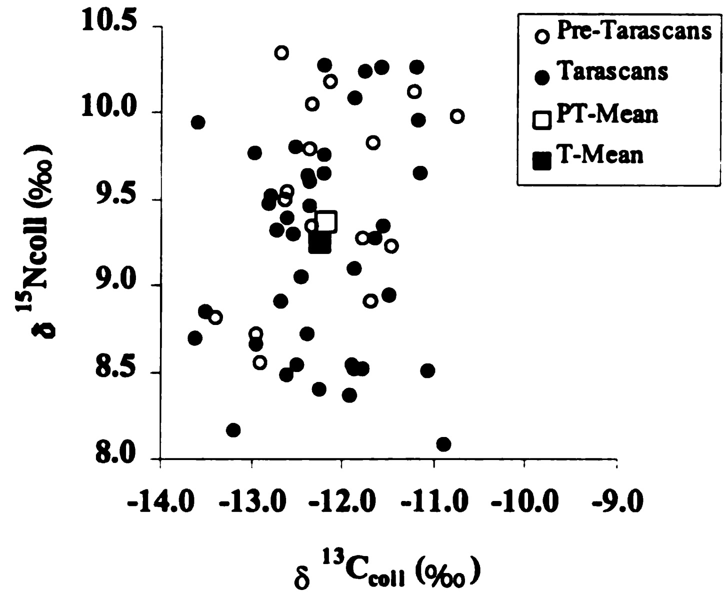

Figure 12. $\delta^{13}C$ and $\delta^{15}N$ values for Pre-Tarascan and Tarascan elites.

diversity challenged the state's economic and political power. To ensure economic exploitation of populations and resources, and to secure the integrity of its frontiers, the state had to integrate these communities (Pollard, 1993).

The Sayula Basin was in the ethnic segregation zone, out in the frontiers of the state. The Tarascan burials from the Sayula Basin are all males from Area 3 at Atoyac (Amacueca phase), and they represent individuals buried with Tarascan burial goods.

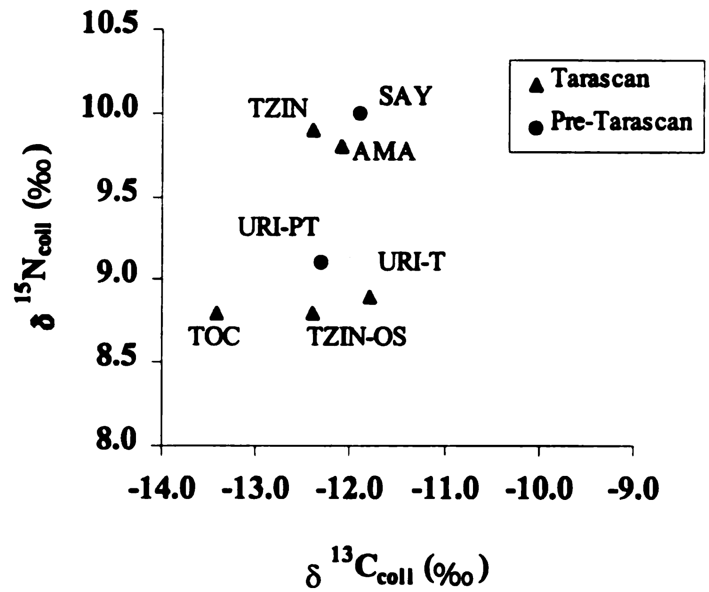

Figure 13. $\delta^{13}C$ and $\delta^{15}N$ values for elites in Pre-Tarascan and Tarascan sites.

Current interpretations are that these individuals represent Tarascan administrators sent out from the geopolitical core to secure the extraction of resources (primarily silver and gold) and ensure the loyalty of local populations to the state, and Tzintzuntzan elites in particular (Valdez and Liot, 1996). Dietary signals are fixed by young adulthood, and stable carbon and nitrogen isotopes do not detect dietary shifts that occur later in life (Stenhouse and Baxter, 1979). All the males at Atoyac (Sayula and Amacueca) are between 25 and 50 years of age. Thus, the stable isotope data is measuring the diets consumed early in life. If the "Tarascan" administrators were sent out as adults, it is not surprising that their diet would be close to that of the Tzintzuntzan elite. If they were local elites who acquired a Tarascan ethnic identity, the data may indicate that diet served as an ethnic marker, depending on when the Tarascan identity was acquired. While the loyalty of these administrators may have been assumed by Tzintzuntzan, the danger of insurrection may have been reduced by providing the administrators with resources (including food items) that identified them with the state. The consumption of foods like those consumed by the Tzintzuntzan elite would have been an effective ethnic and status marker, and a source of power for local elites. Stable oxygen isotope analysis is in progress to determine if these individuals spent their developing years in the Lake Pátzcuaro Basin, or in the Sayula Basin.

A focus on the Sayula Basin reveals that male elites seem to have experienced a slight temporal decrease in $\delta^{15}N$, possibly reflecting a downward trophic level shift. Valdez and Liot (1996) argue that subsistence strategies in the Sayula Basin underwent seasonal shifts as the lake bed dried, exposing rich salt beds. They propose that the population in the Sayula Basin practiced agriculture during the rainy season and stored surpluses for consumption during the dry season, when they specialized in the production of salt. Salt was used in exchange networks to supplement their needs. Earlier populations are believed to have relied more on hunting and gathering than maize agriculture (Valdez and Liot, 1996).

Estimates of population density in the Sayula Basin show an increasing trend, as settlements move further away from the lakeshore into the uplands. An increase in population density may have reduced the game available for consumption, reducing dietary trophic levels and relative $\delta^{15}N$ values (10.0 to 9.8‰, although not statistically significant). Furthermore, the Basin's incorporation into the Tarascan territory would have increased demands for tribute items (metals, salt and minerals). To meet tribute demands, people would have diverted their labor energy toward the production of salt and mining for metals, and away from hunting activities. Assuming that the Amacueca sample does represent Tarascan administrators sent from Tzintzuntzan, they would have used power derived from their ethnic and elite status to exact maize and animal protein from local tribute.

Temporal trends in the Lake Pátzcuaro Basin can only be evaluated at the site of Urichu. The $\delta^{13}C$ and $\delta^{15}N$ values for the Pre-Tarascan sample (Area 5) and the Tarascan sample (Area 1) show an increase in maize and a decrease in animal protein. The Mann-Whitney U tests, however, show that the differences are statistically insignificant.

Within the Lake Pátzcuaro Basin, Tarascan sites below Rank 2 (Urichu and Tócuaro) cluster together in terms of $\delta^{15}N$ values, suggesting that their levels of meat protein were similar. Urichu has a slightly higher (although not statistically significant) mean $\delta^{15}N$ value, but significantly higher (less negative) $\delta^{13}C$ values. The hypothesis that elites in administrative centers in the Lake Pátzcuaro Basin consumed the same relative proportions of maize is not supported by this data. Figure 13 clearly shows that the diet of elites at Tzintzuntzan was different from the diets of elites in Tócuaro (Rank 4/5), and Urichu (Rank 3).

The $\delta^{13}C$ data show that the elite at Tócuaro consumed less maize than at Urichu and Tzintzuntzan. The $\delta^{15}N$ values between Urichu (Rank 3) and Tócuaro (Rank 4/5) do not differ significantly, but the difference between Urichu and Tzintzuntzan is significant. Comparing the $\delta^{15}N$ mean value of Tócuaro with that of Tzintzuntzan, the greatest difference is evident. The 1.1‰ difference in $\delta^{15}N$ mean values clearly indicates that the Tzintzuntzan elite consumed more meat protein, possibly deer, since this resource was coming into the Basin as a tributary item and did not flow through the market network. If the Tócuaro elite were obtaining their meat from non-elites though local tribute, deer and rabbit would not have been a significant part of the diet. Another factor affecting the Tócuaro diet is population density. Estimates for population density at Tócuaro and surrounding settlements indicate that this portion of the Lake Pátzcuaro Basin was the most densely populated (McCosh, et al., 1999).

The Tarascan elites in Tzintzuntzan are consuming more animal protein than the elites in the administrative centers, except for those elites out in the state's frontier borders. This difference in the allocation of such an important food resource parallels the stratified status structure of the state, a trend that is less apparent in the distribution of maize. The elites from administrative centers may have been less willing to tolerate a shortage of maize compared to animal protein, in their diets. The position of their settlement (rank) within the state's sociopolitical structure may have influenced the power of administrative elites to acquire resources.

Within Tzintzuntzan, the Tzintzuntzan-Ossuary sample has a $\delta^{13}C$ value that is the same as that of the Tzintzuntzan elite, and a $\delta^{15}N$ mean that is lower. These data may indicate that the Tzintzuntzan elite's diet was at a slightly higher trophic level. The Tzintzuntzan elite may have consumed relatively more meat (Schoeninger, 1985), or they could have been exploiting more aquatic resources, higher in ^{15}N than terrestrial (Katzenberg, 1989).

The $\delta^{13}C$ and $\delta^{15}N$ mean values of the Tzintzuntzan-Ossuary sample cluster more closely with Urichu (Figure 13), indicating that their diet was similar to that of Rank 3 administrative elites. This finding does not support the hypothesis that the Tzintzuntzan-

Ossuary individuals had a diet similar to the diet of the Tzintzuntzan elite. The warriors captured by the Tarascan army would have been members of elite society. If these men resided in their respective communities, they would have been consuming diets similar to those of other elites. It appears that the consumption of any C_4-based ceremonial foods or beverages may have been too infrequent, or occurred too late in life to leave a discernible isotopic signature. Therefore, any differences in diet between the Tzintzuntzan-ossuary individuals and those from the main platform at Tzintzuntzan morelikely, reflect the elite status of the victims used in sacrificial ceremonies that were captured during wars.

The samples in the study did not allow adequate tests of differences between males and females. In spite of this limitation, bivariate plots of the $\delta^{13}C$ and $\delta^{15}N$ mean values for males and females at each site do show some trends. Figure 14 shows that among females alone, the Tzintzuntzan females have the highest $\delta^{15}N$ mean value (10.1 $\pm$ 1.2), and are clearly different from females at all the other sites in the Lake Pátzcuaro Basin (including the Pre-Tarascan group).

The Tzintzuntzan females differ in mean $\delta^{15}N$ values from their Urichu, Tzintzuntzan-Ossuary, and Tócuaro counterparts by 1.1‰, 1.4‰ and 1.6‰, respectively. Assuming the sample sizes were adequate, the magnitude of the variation within the Tzintzuntzan female sample is still a problem for detecting a statistically significant difference (see Chapter 4 for discussion).

The Tarascans forged kinship ties to conquered settlements by marrying females of local elite families. The degree of variation within the Tzintzuntzan female group may be a reflection of exogamy. After marriage to Tarascan nobility, these women would move to the Lake Patzcuaro Basin, and in particular to Tzintzuntzan (Pollard, 1993).

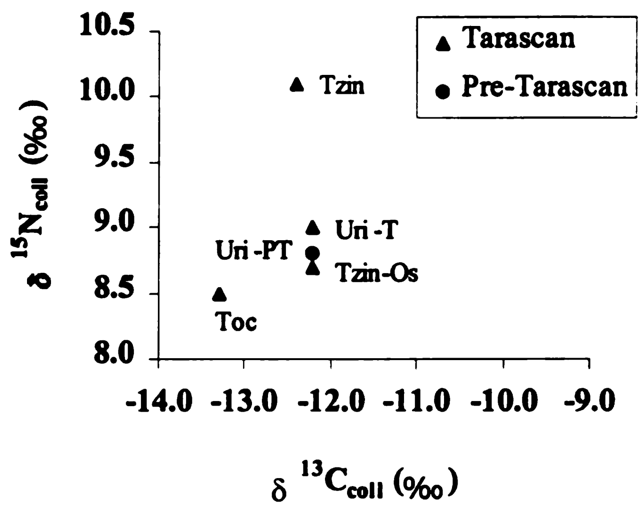

Figure 14. Mean $\delta^{13}C$ and $\delta^{15}N$ values for Pre-Tarascan and Tarascan females.

Amacueca male samples from Atoyac in the Lake Sayula Basin cluster close to Tzintzuntzan males and have the highest $\delta^{15}N$ values (Figure 15). The Tzintzuntzan males also show an elevated $\delta^{15}N$ mean value compared to males elsewhere in the Lake Pátzcuaro Basin, but the magnitude of this difference is not as large as that shown by females. The only statistically significant difference is found between males at Urichu (8.8 + 0.5) and males at Amacueca (9.8 + 0.6) (Mann-Whitney U: $U' > U_{crit} > U$; $p > 0.5$). Of the Tarascan group, males in the Tzintzuntzan-Ossuary have higher $\delta^{15}N$ mean values than Tócuaro and Urichu males; the Urichu males have the lowest value.

Is the elevated $\delta^{15}N$ mean value of females in Tzintzuntzan a record of diet, or does it signal metabolic and physiological stress? If the former were to be assumed, the idea that females consumed more animal protein than males is worthy of thorough investigation, especially since the Tarascan state was firmly set on a system of gender stratification. Yet, this elevated $\delta^{15}N$ may reflect an increased exploitation of aquatic resources (fish), of which there were plenty. Gender divisions of labor were flexible among commoners but less so among elites. The *ireri*, the king's wife, ran the place, and supervised elite women in various positions (Pollard, 1993). There were those who ground corn, those who prepared the fish, and those who brought him drinks, among many others (RM, 1980).

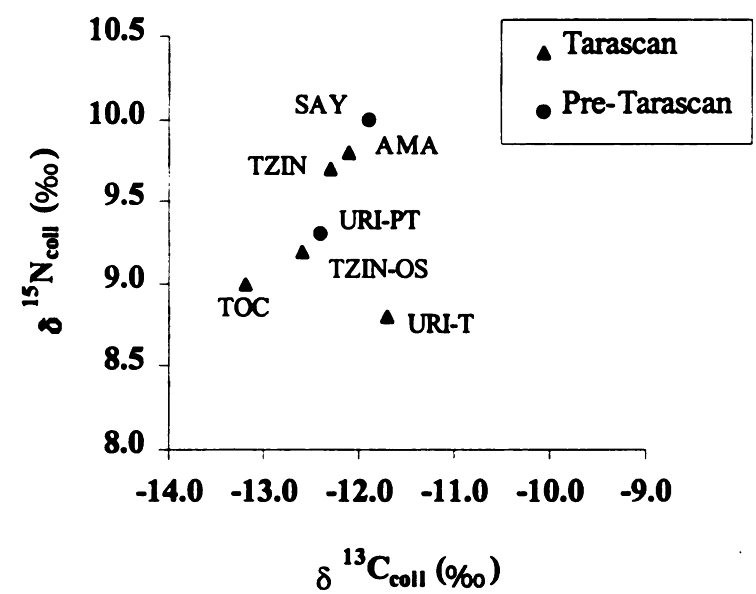

Figure 15. Mean $\delta^{13}C$ and $\delta^{15}N$ values for Pre-Tarascan and Tarascan males.

Among contemporary Tarascans, women are in charge of preparing food. While they will serve men first before serving themselves, women will "sample" the food as it is being prepared, and in fact, many will have their "meals" by the cooking fire. In many instances, the quality of the foods they consume may not be the most culturally desirable, but in terms of nutrition they are as valuable. Women may save the breast, legs and thighs of a duck or turkey for men, and eat the liver, heart, feet and neck themselves. It is difficult to imagine hungry women not taking small portions of meat as they prepared the meals for the king.

CONCLUSIONS

The inability of the Lake Pátzcuaro Basin to support its population as the Tarascan state developed created pressure on local populations to gain access to resources, in particular food. The non-elite specialized in the exploitation of lacustrine resources, which they would exchange for needed items through the state's market networks. The elite obtained their goods directly from Tzintzuntzan, where all tribute items were stored for later distribution. In addition, local tribute and outright ownership of local production were important sources of goods for elites at administrative centers. These strategies served to protect elites from the potentially harmful consequences of dietary change. This study used dietary change as a measure of the power of elites to maintain their diet. As a regional group, the elite had enough power to obtain maize and other resources that functioned as elite markers.

Within the region, however, the power of elites seems to have varied. The isotopic data reveals that there was variation in diet between sites. This variation clearly reflects the rank of elite centers and suggests that elites in lower rank centers obtained less maize and animal protein foods than elites at higher rank centers.

Another unexpected finding was the similarity in diet between the Atoyac-Amacueca males, and the Tzintzuntzan elite. Although distant from Tzintzuntzan, the need to ensure political loyalty to the state prompted Tzintzuntzan to place highly ranked, loyal elites at this settlement to administer the exploitation of labor and resources and to avert any insurrections. Because dietary signals are fixed by adulthood, these individuals may have acquired the Tzintzuntzan dietary signal before leaving Tzintzuntzan, or at Atoyac in the Sayula Basin. If the signal was acquired at Atoyac, dietary signals may be serving as ethnic makers and a signal for power. To evaluate the place of origin, oxygen and strontium isotopes are currently being analyzed. The dietary evidence in this study shows that the people represented in the Tzintzuntzan-Ossuary may represent sacrificed captured warriors from enemy elite centers.

CONTRIBUTIONS, LIMITATIONS AND FUTURE RESEARCH

This dissertation makes a valuable contribution to Tarascan prehistory in that it is the first study to address the effect of political economic processes on the biology of human populations. The greatest strength of the study is that it challenges uni-dimensional explanations for the dietary and health patterns among human populations. While incomplete, the study provides an essential foundation for the building of a comprehensive and systematic research program in the region.

The focus on elites in this study brings into sharp view the debate over the role of elites in the development of socioeconomic inequality. Are elites system-serving individuals using their power for the good of the community (providing access to resources in times of need), or, are they self-serving individuals who exploit and manipulate the population for their own benefit (Hayden, 1990)? If elites were system-serving, the non-elite populations at the administrative centers would have consumed nutritionally adequate diets, even if different from elite diets. To address this question it is necessary to first evaluate the effect of state formation and environmental change on the diet and health of both elites and non-elites. A comparison of elites to non-elites, while ideal, was not possible at the time this study was conducted. To date, non-elite skeletal materials have not been recovered. One way in which to correct this bias in the skeletal record is to conduct field excavations at sites that are not elite centers, e.g., market settlements.

Does the ethnohistoric record truly reflect the nutritional status and health of the Tarascan elites? Are the apparent trends in dietary differences between males and females an artifact of inadequate sampling? How did populations at other basins cope with their incorporation into the state? Current interpretations are that these individuals represent Tarascan.

To answer these questions, it will be necessary to address the most serious limitation of this study: sample size. Plans are to collect samples from Tingambato (Pre-Tarascan), and to expand the Atoyac (Pre-Tarascan and Tarascan) samples.

A project to examine the role of maize in the socio-political and economic shifts detected in the Zacapu Basin is scheduled to begin January, 2001. As part of his project, temporal shifts in diet will be examined, the skeletal materials will be systematically studied to assess their nutritional status and health, and a comprehensive study of the isotopic ecology of the Pátzcuaro, Zacapu, Sayula and Cuitzeo basins will be completed.

The independent and systematic study of health and nutrition is urgent in West Mexico. As cultural-historical models of west Mexican prehistory are replaced, new hypotheses emerge about the role regional and interregional interactions have on the emergence or suppression of local elites. Local, regional and imperial elites affected the nature of interaction within Mesoamerica. How were these social, political and economic shifts experienced by people, the real actors forging these behavioral patterns? What was the effect of social complexity on the health or the populations of west Mexico?

Today, the relationship to the lake of the diverse, but mostly Tarascan (Pureh'pecha) population in the Pátzcuaro basin parallels prehistoric patterns in many ways. Since 1990, the lake level has been receding and exposing fertile land. This exposure of fertile land has come at a time when national and international political and economic policies have resulted in shifts in land ownership and access to resources, especially food. The effects of these shifts and the competition for control of resources, have resulted in a reconfiguration of sociopolitical and economic power within, and between, the basin's communities. Because the traditional Tarascan (Pureh'pecha) diet continues to be mainly composed of maize, beans, chile and fish, the current changes in the environment, and sociopolitical and economic power are sure to have an effect on the health of people living in the Lake Pátzcuaro basin, particularly that of the Tarascan (Pureh'pecha) populations.

APPENDICES

APPENDIX A

LIST OF SAMPLES INCLUDED IN THE STUDY

TABLE A1.

Samples Included in the Study

Burial	Area	Unit	Date		Sex	Age
URICHU						
1	1	Unit 3	Late Postclassic	Tarascan	M	50+
2.1	1	Unit 3	Late Postclassic	Tarascan	M	50+
2.2	1	Unit 3	Late Postclassic	Tarascan	M	12-20
4	1	Unit 4	Late Postclassic	Tarascan	M	35-49
5	1	Unit 2	Late Postclassic	Tarascan	M	12-20
6	1	Unit 4	Late Postclassic	Tarascan	F	35-49
7	1	Unit 4	Late Postclassic	Tarascan	F	35-49
8	1	Unit 5	Late Postclassic	Tarascan	F	50+
9.1	1	Unit 5	Late Postclassic	Tarascan	U	12-13
10	1	Unit 5	Late Postclassic	Tarascan	M	35-49
11	1	Unit 5	Late Postclassic	Tarascan	M	20+
12	5	Tomb	Epi-class - EPC	Pre-Tarascan	F	20-34
13	5	Tomb	Epi-class	Pre-Tarascan	U	12-20
14	5	Tomb	Epi-class	Pre-Tarascan	M	20+
17	5	N1E1	Early Post-class	Pre-Tarascan	F	20-34
18.1	5	Tomb	Epi-class - EPC	Pre-Tarascan	F	20-34
18.2	5	Tomb	Epi-class - EPC	Pre-Tarascan	M	12-20
19.1	5	Tomb	Classic	Pre-Tarascan	M	20+
19.2	5	Tomb	Classic	Pre-Tarascan	M	20+

TABLE A1 (cont'd).

Burial	Area	Unit	Date		Sex	Age
URICHU, Cont.						
21.1	5	Tomb	Classic	Pre-Tarascan	M	20-34
21.2	5	Tomb	Classic	Pre-Tarascan	M	20-34
24	5	N5E2	Classic	Pre-Tarascan	F	20-34
26	1	N11 E8	Late Postclassic	Tarascan	M	35-49
28	1	N12 E7	Late Postclassic	Tarascan	M	20-34
30	1	N12 E7	Late Postclassic	Tarascan	F	35-49
31	1	N12 E7	Late Postclassic	Tarascan	M	20-34
32	1	N10 E7	Late Postclassic	Tarascan	F	50+
33	1	N9 E6	Late Postclassic	Tarascan	F	35-49
34	2		Early Postclassic	Pre-Tarascan	F	20+
TZINTZUNTZAN						
Indiv 1	Y3/PNW	Ent. 3	Late Postclassic	Tarascan	M	20-34
Indiv 2	Y3/PNW		Late Postclassic	Tarascan	F	20-34
Indiv 3	Ed. B		Late Postclassic	Tarascan	F	20-34
Indiv 4	Ed. F	Ent 3.4a	Late Postclassic	Tarascan	M	20+
Indiv 5	Ed. F	Ent 3.4b	Late Postclassic	Tarascan	M	20+
Indiv 6	Ed. F	Ent 3.4c	Late Postclassic	Tarascan	M	20+
Indiv 7	Y3/PNW		Late Postclassic	Tarascan	M	20+
Indiv 8	Y3/PNW		Late Postclassic	Tarascan	M	20-34
Indiv 9	Y3/PNW	Ent. 7a	Late Postclassic	Tarascan	F	35-49

TABLE A1 (cont'd).

Burial	Area	Unit	Date		Sex	Age
TZINTZUNTZAN, Cont.						
Indiv 10	Y3/NW	Ent. 7b	Late Postclassic	Tarascan	F	12-20
Indiv 11	Tzin VI	Platform	Late Postclassic	Tarascan	F	20+
Indiv 12	Tzin VI	Platform	Late Postclassic	Tarascan	F	20+
Indiv 13	Tzin VI	Platform	Late Postclassic	Tarascan	M	20+
TZINTZUNZTAN-Ossuary						
Indiv 1	Ossuary		Late Postclassic	Tarascan	F	20-34
Indiv 2	Ossuary		Late Postclassic	Tarascan	M	50+
Indiv 3	Ossuary		Late Postclassic	Tarascan	F	35-49
Indiv 4	Ossuary		Late Postclassic	Tarascan	M	20-34
Indiv 5	Ossuary		Late Postclassic	Tarascan	F	20-34
TOCUARO						
1	7A	Capa I	Late Postclassic	Tarascan	M	35-49
2	6A-7A	Capa I	Late Postclassic	Tarascan	M	35-49
3.1	8B	Capa I	Late Postclassic	Tarascan	U	20+
3.2	8B	Capa I	Late Postclassic	Tarascan	U	20+
4	6A-7B	Capa I	Late Postclassic	Tarascan	F	20-34
6	6A	Capa I	Late Postclassic	Tarascan	F	20+
7	8B	Capa I	Late Postclassic	Tarascan	U	7-8
8	U.E. 3/2	Capa II	Late Postclassic	Tarascan	M	35-49

TABLE A1 (cont'd).

Burial	Area	Unit	Date		Sex	Age
ATOYAC-Sayula Phase						
18.1	2		Epi-Classic	Pre-Tarascan	M	30-35
23.1	2		Epi-Classic	Pre-Tarascan	M	35-39
24.1	2		Epi-Classic	Pre-Tarascan	M	30-35
35.1	2		Epi-Classic	Pre-Tarascan	M	44-50
49.1	2		Epi-Classic	Pre-Tarascan	M	30-35
ATOYAC-Amacueca Phase						
60.1	3		Late Postclassic	Tarascan	M	25-35
64.1	3		Late Postclassic	Tarascan	M	25-35
76.1	3		Late Postclassic	Tarascan	M	45-50
79.1	3		Late Postclassic	Tarascan	M	35-39
82.1	3		Late Postclassic	Tarascan	M	35-45

APPENDIX B

MANN-WHITNEY U TESTS

TABLE B1

$\delta^{13}C_{coll}$ (‰) For Amacueca and Tocuaro Elites

Raw Measures		Ranked Measures		Mann-Whitney U Test
AMA	TOC	AMA	TOC	Two-Tailed test, p = 5%
$n_1 = 5$	$n_2 = 6$	$n_1 = 5$	$n_2 = 6$	
-12.7	-13.6	7	1.5	**n_1 = n of smaller sample**
-12.2	-13.6	8.5	1.5	**n_1 = n of larger sample**
-12.2	-13.5	8.5	3	**R1 = sum of ranks for smaller sample**
-11.9	-13.3	10	4.5	**$U = [n_1n_2 + n_1(n_1 + 1)/2] - R_1$**
-11.6	-13.3	11	4.5	**$U' = n_1n_2 - U$**
	-13.2		6	
				CALCULATIONS
				$n_1n_2 = 30$
				$n_1(n_1+1)/2 = 15$
				$U = 0$
				$U' = 30$
				$U_{crit} = 3$
				EVALUATE HYPOTHESES
				Reject Ho and accept Ha if: smaller of U and U' is less than or equal to Ucrit
n =		5	6	
SUM of RANKS		45	21	
AVG. of RANKS		9.0	3.5	

Ho: There is no significant difference in mean $\delta\ ^{13}C_{coll}$ between TOC and AMA elites.
Ha: There is a significant difference in mean $\delta\ ^{13}C_{coll}$ between TOC and AMA elites.
$U' > U_{crit} > U$: reject the Ho. **P> 0.05**

TABLE B2

Example of Mann-Whitney U Test Worksheet - Z Approximation

Raw Measures		**Ranked Measures**	
Pre-Tar $n_1 = 11$	**Tarasca** $n_2 = 27$	**Pre-Tar** $n_1 = 11$	**Tarascan** $n_2 = 27$
-12.9	-13.6	5	1.5
-12.9	-13.6	5	1.5
-12.7	-13.3	10	3
-12.6	-12.9	13.5	5
-12.6	-12.8	13.5	7.5
-12.4	-12.8	18	7.5
-12.3	-12.7	19	10
-12.2	-12.7	21	10
-11.5	-12.6	31.5	13.5
-11.2	-12.6	34	13.5
-10.8	-12.5	38	16.5
	-12.5		16.5
	-12.2		21
	-12.2		21
	-11.9		24.5
	-11.9		24.5
	-11.9		24.5
	-11.9		24.5
	-11.8		27.5
	-11.8		27.5
	-11.6		29.5
	-11.6		29.5
	-11.5		31.5
	-11.2		34
	-11.2		34
	-11.1		36
	-10.6		37
	n =	11	27
SUM of RANKS		208.5	557
AVG. of RANKS		19.0	19.9

Mann-Whitney U Test

Two-Tailed test, p = 5% (0.05)

n_1 = n of smaller sample

n_2 = n of larger sample

R1 = sum of ranks for smaller sample

$U = [n_1 n_2 + n_1(n_1 + 1)/2] - R_1$

$U' = n_1 n_2 - U_1$

$n_1 n_2 = 297$

$n_1(n_1+1)/2 = 66$

$U = 154.5$

$U' = 142.5$

When n_2 increases in size, the sampling distribution approximates normality.

$$\text{Mean} = \mu_U = n_1 n_2 / 2$$

$$\text{S. D} = \sigma_U = \sqrt{\frac{n_1 n_2 (n_1+n_2+1)}{12}}$$

$$Z = \frac{U - \mu_U}{\sigma_U}$$

Reject Ho and accept Ha if the positive value of Z_U is greater than Z_{crit}

$Z_U = 0.19$

$Z_{crit} = 1.96$

Ho: There is no significant difference in mean $\delta\ ^{13}C_{coll}$ between PT and T males

Ha: There is a significant difference in mean $\delta\ ^{13}C_{coll}$ between PT and T males

$Z_{crit} > Z_U$: the test fails to reject the Ho.

TABLE B3

Summary of Mann-Whitney U Tests for Mean $\delta^{13}C_{coll}$ Values (Two-Tailed, $p = 0.05$)

TEMPORAL SHIFTS	n	$\delta^{13}C_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Pooled Samples			Z_U		Z_{crit}		
Pre-Tarascans	17	-12.2	0.08		1.96	**for n_1, n_2 >20**	$Z_{crit}>Z_U$
Tarscans	45	-12.3				**$Z_U>Z_{crit}$**	Fail to reject Ho
Urichu - Patzcuaro Basin							
Pre-Tarascans	12	-12.3	134	58	53	U>U'≤Ucrit	U>U'>Ucrit
Tarascans	16	-11.8				U'>U≤Ucrit	Fail to reject Ho
Atoyac - Sayula Basin							
Sayula (Pre-Tarascans)	5	-11.9	11.5	13.5	2	U>U'≤Ucrit	U'>U>Ucrit
Amacueca (Tarascans)	5	-12.1				U'>U≤Ucrit	Fail to reject Ho
TARASCAN ADMINISTRATIVE CENTERS							
Tzintzuntzan	13	-12.4	26	39	12	U>U'≤Ucrit	U'>U>Ucrit
Amacueca	5	-12.1					Fail to reject Ho
Tzintzuntzan	13	-12.4	143.5	64.5	59	U>U'≤Ucrit	U>U'>Ucrit
Urichu	16	-11.8				U'>U≤Ucrit	Fail to reject Ho

TABLE B3 (cont'd).

	n	$\delta^{13}C_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Tzintzuntzan	13	-12.4	72	6	16	U>U'≤Ucrit	U>Ucrit>U'
Tocuaro	6	-13.4				U'>U≤Ucrit	**Reject Ho**
Urichu	16	-11.8	96	0	21	U>U'≤Ucrit	U>Ucrit>U'
Tocuaro	6	-13.4				U'>U≤Ucrit	**Reject Ho**
MALE AND FEMALE DIFFERENCES							
Pre-Tarascan							
Males	11	-12.2	25.5	29.5	11	U>U'≤Ucrit	U'>U>Ucrit
Females	5	-12.2				U'>U≤Ucrit	Fail to reject Ho
Tarascan							
Males	27	-12.2	234	198	138	U>U'≤Ucrit	U>U'>Ucrit
Females	16	-12.4				U'>U≤Ucrit	Fail to reject Ho
Tarascan Males							
Tzintzuntzan	7	-12.3	53	17	14	U>U'≤Ucrit	U>U'>Ucrit
Urichu	10	-11.7				U'>U≤Ucrit	Fail to reject Ho
Tzintzuntzan	7	-12.3	21	0	1	U>U'≤Ucrit	U>Ucrit>U'
Tocuaro	3	-13.5				U'>U≤Ucrit	**Reject Ho**

TABLE B3 (cont'd).

	n	$\delta^{13}C_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Tzintzuntzan	7	-12.3	12	23	5	U>U'≤Ucrit	U'>U>Ucrit
Amacueca	5	-12.1				U'>U≤Ucrit	Fail to reject Ho
Urichu	10	-11.7	30	0	3	U>U'≤Ucrit	U>Ucrit>U'
Tocuaro	3	-13.5				U'>U≤Ucrit	**Reject Ho**
Urichu	10	-11.7	39	11	8	U>U'≤Ucrit	U>U'>Ucrit
Amacueca	5	-12.1				U'>U≤Ucrit	Fail to reject Ho
Tocuaro	3	-13.5	15	0	0	U>U'≤Ucrit	U>U' = Ucrit
Amacueca	5	-12.1				U'>U≤Ucrit	**Reject Ho**
Tarascan Females							
Tzintzuntzan	6	-12.4	18	18	5	U>U'≤Ucrit	U = U' >Ucrit
Urichu	6	-12.2				U'>U≤Ucrit	Fail to reject Ho
Tzintzuntzan	6	-12.4	8.5	9.5	1	U>U'≤Ucrit	U'>U>Ucrit
Tzin-Ossuary	3	-12.2				U'>U≤Ucrit	Fail to reject Ho
Urichu-Pre-Tarascan							
Males	6	-12.4	11.5	18.5	3	U>U'≤Ucrit	U'>U>Ucrit
Females	5	-12.2				U'>U≤Ucrit	Fail to reject Ho

TABLE B3 (cont'd).

	n	$\delta^{13}C_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Urichu-Tarascan							
Males	10	-11.7	46.5	13.5	11	U>U'≤Ucrit	U>U'>Ucrit
Females	6	-12.2				U'>U≤Ucrit	Fail to reject Ho
Tzintzuntzan							
Males	7	-12.3	19.5	22.5	6	U>U'≤Ucrit	U'>U>Ucrit
Females	6	-12.4				U'>U≤Ucrit	Fail to reject Ho
Pooled Females							
Pre-Tarascans	5	-12.2	36.5	48.5	15	U>U'≤Ucrit	U'>U>Ucrit
Tarascans	17	-12.4				U'>U≤Ucrit	Fail to reject Ho
Pooled Males			**Z_U**		**Z_{crit}**		
Pre-Tarascans	11	-12.2	0.19		1.96	**for n_1, n_2 >20**	Z_{crit}>Z_U
Tarascans	27	-12.2				**Z_U>Z_{crit}**	Fail to reject Ho
Pre-Tarascans and Tarascans			**Z_U**		**Z_{crit}**		
Females	22	-12.4	0.44		1.96	**for n_1, n_2 >20**	Z_{crit}>Z_U
Males	38	-12.2				**Z_U>Z_{crit}**	Fail to reject Ho

TABLE B4

Summary of Mann-Whitney U Tests for Mean $\delta^{15}N_{coll}$ Values (Two-Tailed, $p = 0.05$)

TEMPORAL SHIFTS	n	$\delta^{15}N_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Pooled Samples							
Pre-Tarascan	17	9.4	Z_U		Z_{crit}	**for n1, n2>20**	$Z_{crit}>Z_U$
Tarascan	45	9.3	1.13		1.96	$Z_U>Z_{crit}$	Fail to reject Ho
Urichu - Patzcuaro Basin							
Pre-Tarascans	12	9.1	75.5	116.5	53	U>U'≤Ucrit	U'>U>Ucrit
Tarascans	16	8.9				U'>U≤Ucrit	Fail to reject Ho
Atoyac - Sayula Basin							
Sayula (Pre-Tarascans)	5	10.0	11.5	13.5	2	U>U'≤Ucrit	U'>U>Ucrit
Amacueca (Tarascans)	5	9.8				U'>U≤Ucrit	Fail to reject Ho
TARASCAN ADMINISTRATIVE CENTERS							
Tzintzuntzan	13	9.9	27.5	37.5	12	U>U'≤Ucrit	U'>U>Ucrit
Amacueca	5	9.8				U'>U≤Ucrit	Fail to reject Ho
Tzintzuntzan	13	9.9	31.5	176.5	59	U>U'≤Ucrit	U'>Ucrit>U
Urichu	16	9.1				U'>U≤Ucrit	**Reject Ho**

TABLE B4 (cont'd).

	n	$\delta^{15}N_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Tzintzuntzan	13	9.9	66	12	16	U>U'≤Ucrit	U>Ucrit>U'
Tocuaro	6	8.8				U'>U≤Ucrit	**Reject Ho**
Urichu	16	9.1	50	46	21	U>U'≤Ucrit	U>U'>Ucrit
Tocuaro	6	8.8				U'>U≤Ucrit	Fail to reject Ho
MALE AND FEMALE DIFFERENCES							
Pre-Tarascan							
Males	11	9.6	42.5	12.5	11	U>U'≤Ucrit	U>U'>Ucrit
Females	5	8.8				U'>U≤Ucrit	Fail to reject Ho
Tarascan							
Males	27	9.3	44.1	22.3	138	U>U'≤Ucrit	U>U'>Ucrit
Females	16	9.2				U'>U≤Ucrit	Fail to reject Ho
Tarascan Males							
Tzintzuntzan	7	9.7	5.5	64.5	14	U>U'≤Ucrit	U'>Ucrit>U
Urichu	10	8.8				U'>U≤Ucrit	**Reject Ho**
Tzintzuntzan	7	9.7	16	5	1	U>U'≤Ucrit	U>U'>Ucrit
Tocuaro	3	9.0				U'>U≤Ucrit	Fail to reject Ho

TABLE B4 (cont'd).

	n	$\delta^{15}N_{coll}$ (‰) Mean	U	U'	U_{crit}	Criteria to reject Ho	Decision
Tzintzuntzan	7	9.7	13	22	5	U>U'≤Ucrit	U'>U>Ucrit
Amacueca	5	9.8				U'>U≤Ucrit	Fail to reject Ho
Urichu	10	8.8	14	16	3	U>U'≤Ucrit	U'>U>Ucrit
Tocuaro	3	9.0				U'>U≤Ucrit	Fail to reject Ho
Urichu	10	8.8	4.5	45.5	8	U>U'≤Ucrit	U'>Ucrit>U
Amacueca	5	9.8				U'>U≤Ucrit	**Reject Ho**
Tocuaro	3	9.0	13	2	0	U>U'≤Ucrit	U>U'>Ucrit
Amacueca	5	9.8				U'>U≤Ucrit	Fail to reject Ho
Tarascan Females							
Tzintzuntzan	6	10.1	28.5	7.5	5	U>U'≤Ucrit	U>U'>Ucrit
Urichu	6	9.0				U'>U≤Ucrit	Fail to reject Ho
Tzintzuntzan	6	10.1	15.5	2.5	1	U>U'≤Ucrit	U>U'>Ucrit
Tzin-Ossuary	3	8.7				U'>U≤Ucrit	Fail to reject Ho
Urichu-Pre-Tarascan							
Males	6	9.3	18.5	11.5	3	U>U'≤Ucrit	U>U'>Ucrit
Females	5	8.8				U'>U≤Ucrit	Fail to reject Ho

TABLE B4 (cont'd).

		$\delta^{15}N_{coll}$ (‰)					
	n	**Mean**	**U**	**U'**	**U_{crit}**	**Criteria to reject Ho**	**Decision**
Urichu-Tarascan							
Males	10	8.8	26.5	33.5	11	U>U'≤Ucrit	U'>U>Ucrit
Females	6	9.0				U'>U≤Ucrit	Fail to reject Ho
Tzintzuntzan							
Males	7	9.7	16.5	25.5	6	U>U'≤Ucrit	U'>U>Ucrit
Females	6	10.1				U'>U≤Ucrit	Fail to reject Ho
Pooled Females							
Pre-Tarascans	5	8.8	48	37	15	U>U'≤Ucrit	U>U'>Ucrit
Tarascans	17	9.2				U'>U≤Ucrit	Fail to reject Ho
Pooled Males							
Pre-Tarascans	11	9.6	**Z_U**		**Z_{crit}**	**for n_1, n_2 >20**	Z_{crit}>Z_U
Tarascans	27	9.3	1.54		1.96	**Z_U>Z_{crit}**	Fail to reject Ho
Pre-Tarascans and Tarascans							
Females	22	9.1	**Z_U**		**Z_{crit}**	**for n_1, n_2 >20**	Z_{crit}>Z_U
Males	38	9.4	1.44		1.96	**Z_U>Z_{crit}**	Fail to reject Ho

APPENDIX C

STABLE ISOTOPE DATA

TABLE C1

Collagen Extraction Yield, C/N and Stable Carbon and Nitrogen Isotope Values

	SEX	AGE (yrs)	% Yield	C/N	$\delta^{13}C$	$\delta^{15}N$	COMENTS
TARASCAN							
Urichu							
URI-T-1	M	50+	16.37	3.29	-11.07	8.51	
URI-T-2.1	M	50+	8.09	3.38	-11.64	9.27	
URI-T-2.2	M	12-20	9.48	3.34	-11.87	9.10	
URI-T-4	M	35-49	11.42	3.31	-11.17	9.96	
URI-T-5	M	50+	5.59	3.27	-11.91	8.37	
URI-T-6	F	35-49	15.83	3.27	-12.50	8.54	
URI-T-7	F	35-49	8.58	3.29	-12.21	9.76	
URI-T-8	F	50+	12.56	3.24	-12.38	9.64	
URI-T-10	M	35-49	16.94	3.30	-10.89	8.08	
URI-T-11	M	20+	15.86	3.30	-12.94	8.66	
URI-T-26	M	35-49	16.62	3.23	-11.50	8.94	
URI-T-28	M	20-34	11.58	3.29	-11.78	8.52	
URI-T-30	F	35-49	9.30	3.15	-11.55	9.34	
URI-T-31	M	20-34	15.42	3.24	-11.89	8.54	
URI-T-32	F	50+	16.88	3.22	-12.41	7.92	
URI-T-33	F	35-49	9.22	3.27	-11.86	8.52	
URI-T-9.1	***?***	***12-13***	***8.48***	***3.16***	***-14.32***	***9.66***	***Juvenile, REJECTED***

TABLE C1 (cont'd).

	SEX	AGE (yrs)	% Yield	C/N	$\delta^{13}C$	$\delta^{15}N$	COMENTS
Tocuaro							
TOC-T-1	M	35-49	3.76	3.54	-13.61	8.69	
TOC-T-2	M	35-49	14.38	3.43	-13.26	8.4	
TOC-T-3.1	?	20+	7.59	3.54	-13.29	8.72	
TOC-T-4	F	20-34	9.82	3.44	-13.19	8.17	
TOC-T-6	F	20+	2.25	3.61	-13.50	8.85	
TOC-T-8	M	35-49	12.36	3.61	-13.59	9.94	
TOC-T-3.2	***?***	***20+***	***4.52***	***3.83***	***-12.47***	***9.2***	***High C/N, REJECTED***
TOC-T-7	***?***	***7-8***	***17.25***	***3.44***	***-12.27***	***9.26***	***Juvenile,REJECTED***
Tzintzuntzan							
TZN-T-1	M	20-34	8.07	3.43	-11.20	10.27	
TZN-T-2	F	20-34	13.17	3.35	-12.96	9.77	
TZN-T-3	F	20-34	12.63	3.28	-14.64	8.52	
TZN-T-4	M	20+	8.81	3.38	-12.78	9.52	
TZN-T-5	M	20+	9.92	3.35	-12.81	9.47	
TZN-T-6	M	20+	12.30	3.40	-12.60	9.39	
TZN-T-7	M	20+	0.00	3.47	-12.51	9.80	
TZN-T-8	M	20-34	9.48	3.35	-12.55	9.3	
TZN-T-9	F	35-49	17.79	3.28	-11.15	9.65	
TZN-T-10	F	12-20	17.27	3.22	-12.37	9.46	
TZN-T-11	F	20+	20.16	3.24	-11.79	12.02	
TZN-T-12	F	20+	6.14	3.56	-11.76	10.92	
TZN-T-13	M	20+	23.62	3.16	-11.75	10.24	

TABLE C1 (cont'd).

	SEX	AGE (yrs)	% Yield	C/N	$\delta^{13}C$	$\delta^{15}N$	COMENTS
Tzin-Ossuary							
TZN-OS-T-1	F	20-34	15.62	3.29	-12.62	8.48	
TZN-OS-T-2	M	50+	16.16	3.40	-12.45	9.05	
TZN-OS-T-3	F	35-49	9.80	3.22	-12.36	9.6	
TZN-OS-T-4	M	20-34	11.72	3.36	-12.73	9.32	
TZN-OS-T-5	F	20-34	11.80	3.29	-11.74	7.9	
Amacueca							
AMA-T-60.1	M	25-35	8.68	3.22	-12.21	10.28	
AMA-T-64.1	M	25-35	9.74	3.24	-12.67	8.91	
AMA-T-76.1	M	45-50	9.13	3.23	-12.21	9.65	
AMA-T-79.1	M	35-39	8.82	3.26	-11.57	10.26	
AMA-T-82.1	M	35-45	4.96	3.31	-11.87	10.09	
PRE-TARASCAN							
Sayula							
SAY-PT-18.1	M	30-35	15.45	3.28	-11.22	10.12	
SAY-PT-23.1	M	35-39	22.28	3.31	-12.15	10.18	
SAY-PT-24.1	M	30-35	9.20	3.24	-12.63	9.5	
SAY-PT-35.1	M	44-50	1.57	3.23	-12.67	10.35	
SAY-PT-49.1	M	30-35	7.82	3.20	-10.75	9.98	

TABLE C1 (cont'd).

	SEX	AGE (yrs)	% Yield	C/N	$\delta^{13}C$	$\delta^{15}N$	COMENTS
Urichu							
URI-PT-12	F	20-34	8.68	3.24	-11.66	9.83	
URI-PT-13	?	20+	10.07	3.29	-12.35	9.34	
URI-PT-14	M	20+	11.48	3.28	-12.33	10.06	
URI-PT-17	F	20-34	11.59	3.15	-11.70	8.91	
URI-PT-18.1	F	20-34	6.76	3.34	-13.39	8.81	
URI-PT-18.2	M	12-20	12.00	3.30	-12.90	8.56	
URI-PT-19.1	M	20+	8.24	3.18	-11.46	9.23	
URI-PT-19.2	M	20+	4.05	3.43	-12.60	9.55	
URI-PT-21.1	M	20-34	7.04	3.28	-12.36	9.79	
URI-PT-21.2	M	20-34	19.96	3.34	-12.94	8.72	
URI-PT-24	F	20-34	4.40	3.42	-11.78	9.27	
URI-PT-34	F	20+	8.10	3.36	-12.39	7.11	

TABLE C2

Replicate C/N and Stable Carbon and Nitrogen Isotope Values

		MAY	JUNE					
SAMPLE ID		**Rep 1**	**Rep 1**	**Rep 2**	**Rep 3**	**MEAN**	**Std Dev**	**Comments**
URI-T-2.1	C/N		3.4	3.37	3.37	3.38	0.02	
	$\delta^{13}C$	-11.71	-11.8	-11.42		-11.64	0.20	
	$\delta^{15}N$		9.07	9.34	9.39	9.27	0.17	
URI-T-4	C/N		3.31			3.31		
	$\delta^{13}C$	-10.89	-11.48	-11.14		-11.17	0.30	
	$\delta^{15}N$		9.96			9.96		
URI-T-10	C/N		3.3			3.30		
	$\delta^{13}C$	-11.01	-10.77			-10.89	0.17	
	$\delta^{15}N$		8.08			8.08		
URI-T-30	C/N	3.22	3.07			3.15	0.11	
	$\delta^{13}C$	-11.55				-11.55		
	$\delta^{15}N$	9.46	9.22			9.34	0.17	

TABLE C2 (cont'd).

SAMPLE ID		MAY Rep 1	JUNE Rep 1	JUNE Rep 2	JUNE Rep 3	MEAN	Std Dev	Comments
URI-T-32	C/N		3.22	3.19	3.24	3.22	0.03	
	$\delta^{13}C$	-12.41				-12.41		
	$\delta^{15}N$		7.82	7.95	8	7.92	0.09	
URI-PT_17	C/N	3.27	3.03			3.15	0.17	
	$\delta^{13}C$	-11.7				-11.70		
	$\delta^{15}N$		8.92	8.9		8.91	0.01	
URI-PT-19.1	C/N	3.31	3.05			3.18	0.18	
	$\delta^{13}C$	-11.46				-11.46		
	$\delta^{15}N$	9.4	9.06			9.23	0.24	
URI-PT-21.2	C/N		3.29	3.38		3.34	0.06	
	$\delta^{13}C$	-12.94				-12.94		
	$\delta^{15}N$		8.83	8.6		8.72	0.16	

TABLE C2 (cont'd).

SAMPLE ID		MAY	JUNE					
		Rep 1	Rep 1	Rep 2	Rep 3	MEAN	Std Dev	Comments
TOC-T-1	C/N		4.19	3.54		3.54		Sample powdered
	$\delta^{13}C$	-13.61				-13.61		and homogenized
	$\delta^{15}N$		8.76	8.69		8.69		Reject June Rep 1
TOC-T-3.1	C/N		4.1	3.54		3.54		Sample powdered
	$\delta^{13}C$	-13.1	-13.3			-13.10		and homogenized
	$\delta^{15}N$		9.21	8.72		8.72		Reject June Rep 1
TOC-T-6	C/N		3.72	3.61		3.61		Sample powdered
	$\delta^{13}C$		-13.74	-13.46	-13.29	-13.50	0.23	and homogenized
	$\delta^{15}N$		8.96	8.85		8.85		Reject June Rep 1
TOC-T-7	C/N		3.94	3.44		3.44		Sample powdered
	$\delta^{13}C$		-12.27			-12.27		and homogenized
	$\delta^{15}N$		8.94	9.26		9.26		Reject June Rep 1

TABLE C2 (cont'd).

SAMPLE ID		MAY Rep 1	JUNE Rep 1	JUNE Rep 2	JUNE Rep 3	MEAN	Std Dev	Comments
TOC-T-8	C/N		4.53	3.61		3.61		Sample powdered
	$\delta^{13}C$		-13.59			-13.59		and homogenized
	$\delta^{15}N$		10.08	9.94		9.94		Reject June Rep 1
TZN-T-7	C/N		3.49	3.45		3.47	0.03	
	$\delta^{13}C$	-12.51				-12.51		
	$\delta^{15}N$		9.91	9.68		9.80	0.16	
TZN-T-12	C/N		3.54	3.58		3.56	0.03	
	$\delta^{13}C$	-11.91	-11.92	-11.46		-11.76	0.26	
	$\delta^{15}N$		10.9	10.94		10.92	0.03	
TZN-Os-T-2	C/N		3.73	3.4		3.57	0.23	
	$\delta^{13}C$	-12.45				-12.45		
	$\delta^{15}N$		9.38	9.05		9.22	0.23	

TABLE C2 (cont'd).

SAMPLE ID		MAY Rep 1	JUNE Rep 1	JUNE Rep 2	JUNE Rep 3	MEAN	Std Dev	Comments
SAY-PT-35.1	C/N		3.23			3.23		
	$\delta^{13}C$	-12.93	-12.61	-12.46		-12.67	0.24	
	$\delta^{15}N$		10.35			10.35		
AMA-T-82.1	C/N		3.31			3.31		
	$\delta^{13}C$		-11.89	-11.84		-11.87	0.04	
	$\delta^{15}N$		10.09			10.09		
AMA-T-64.1	C/N		3.38	3.1		3.24	0.20	
	$\delta^{13}C$		-12.67			-12.67		
	$\delta^{15}N$		8.51	9.3		8.91	0.56	

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