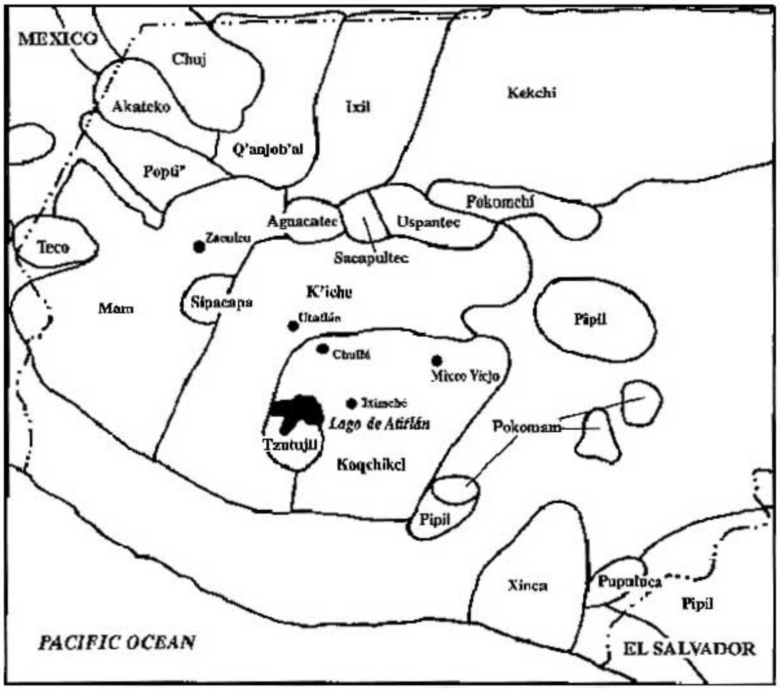
FAMSI © 2000: Stephen L. Whittington & Robert H. Tykot

Analysis of Kaqchikel Skeletons: Iximché, Guatemala



Research Year: 2000
Culture: Maya
Chronology: Late Classic to Post Classic
Location: Guatemala
Site: Iximché

Table of Contents

Introduction

War, prisoners, and human sacrifice were part of the religious complex which influenced the ruling elite and its institutions in Late Postclassic highland Guatemala. Chronicler Friar Francisco Ximénez described human sacrifice as practiced by the people of Guatemala. After extraction of the heart, which was offered to the idol, the heads were put on poles on a special altar dedicated to this purpose, where they remained for some time, after which they were buried. The bodies of the sacrificed were cooked and eaten as sanctified flesh (Guillemin, 1969:27; 1977:258). Aspects of this religious complex show up in the human remains excavated at Iximché, the Kaqchikel Maya capital (Figure 1).

Founded by refugees from the K'iche kingdom in the 1470s or 1480s, Iximché was strategically located on a hilltop surrounded on three sides by steep ravines. Spaniards and their native allies from México arrived in 1524 under the command of Pedro de Alvarado. With the Kaqchikel as allies, they conquered the K'iche and other enemies of Iximché. Alvarado founded the first colonial capital of Guatemala at Iximché. The outbreak of hostilities between the Kaqchikel and the Spanish and a revolt within the Spanish ranks led to the ultimate destruction and abandonment of Iximché in 1526.

George Guillemin excavated Iximché between the late 1950s and the early 1970s. Excavations occurred only within the elite section of the site. Unlike many archaeologists excavating lowland Maya sites during that period, Guillemin seems to have had an intuitive understanding of the value of human remains for interpretation of the past. He carefully excavated and stored almost all of them, although not all are described in detail in his field notes and publications.

Submitted 06/01/2000 by:
Stephen L. Whittington
Hudson Museum
University of Maine
stephen@maine.maine.edu

Robert H. Tykot
Department of Anthropology
University of South Florida

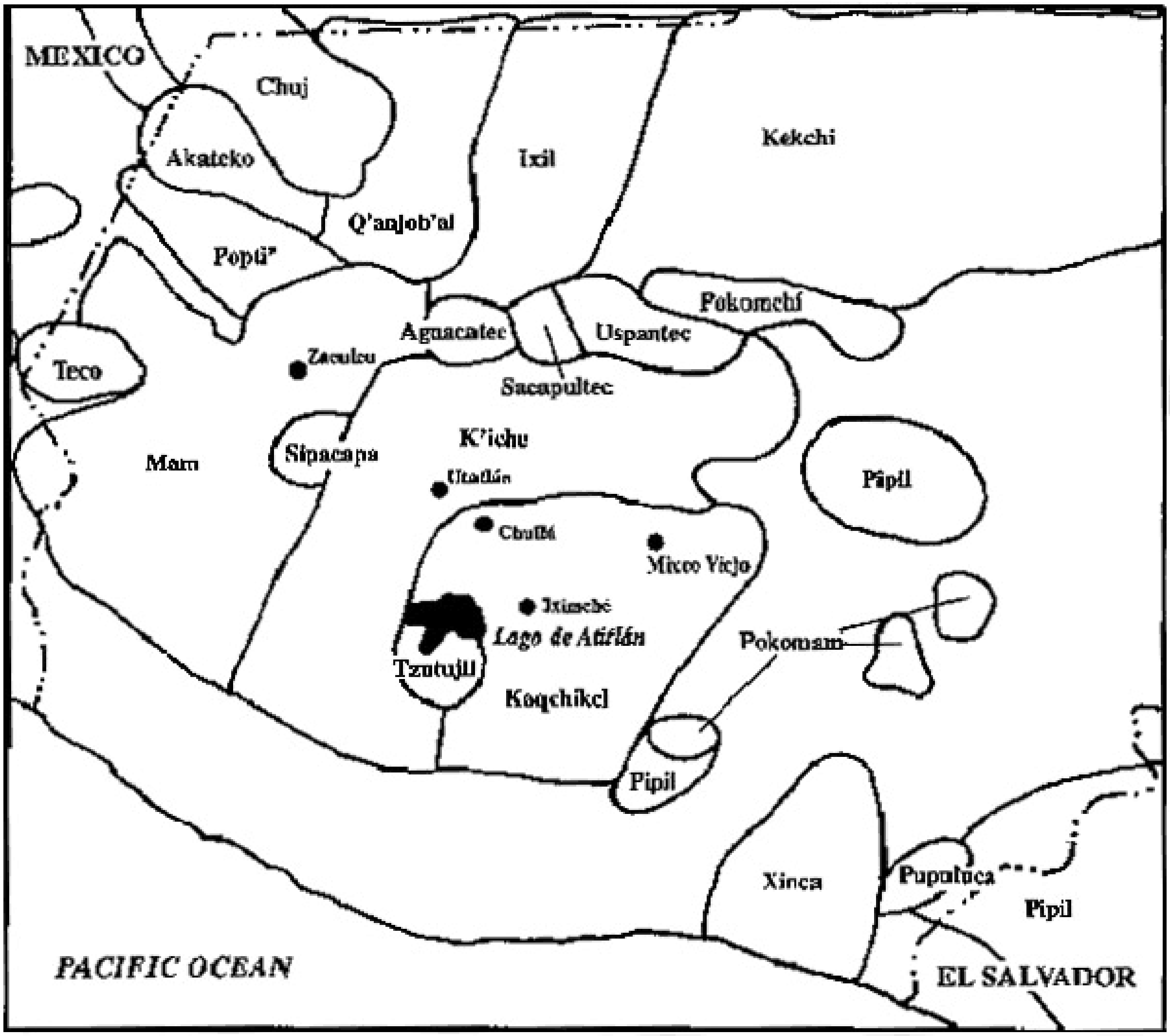


Figure 1. Map of southern Guatemala, showing the location of Iximché in relation to language areas and some important sites.

Previous Related Work at Iximché

In 1991 Edgar Vinicio García of the Instituto de Antropología e Historia introduced Whittington to the site and its excavation history. In 1992 Dave Reed of Penn State University and Whittington began work on the skeletons at a laboratory in Guatemala City. Whittington returned again in 1993 and then, with funding from the Foundation for the Advancement for Mesoamerican Studies, Inc., for a last time in 1995 to perform analysis of age, sex, trauma, and diseases on the skeletons.

At least 66 whole and partial crania are present in the human skeletal sample stored at Iximché. Except for cervical vertebrae it generally is not possible to match cranial with postcranial material due to mixing and loss of provenience information which occurred in storage between the time of excavation and analysis. Guillemin's notes and publications indicate that at least 50 crania are from decapitations. Only 17 of the 66 crania could be visually matched with excavation photos of crania which Guillemin identified as decapitations. These are considered to be confirmed *Decapitations*. Nearly all of them have damage identified as arising from the process of decapitation on the cranial bones or on associated cervical vertebrae. The majority came from a group of 48 decapitated crania deposited together adjacent to Structure 104 in Plaza C, which Guillemin identified as a skull rack.

Fourteen of the 66 crania are *Decapitations*?, which fall into one of four categories. For 11, damage identified as arising from the process of decapitation appears on the crania or associated cervical vertebrae, but they could not be matched with crania in excavation photos. In one case, documentation found with the bones appears to be reliable and places it within the group of 48 decapitations, even though the cranium could not be matched to an excavation photo and no decapitation damage appears. In one case, the cranium was associated with postcranial bones, but decapitation damage also appears. Finally, in one case, a cranium with decapitation damage was matched to excavation photos which also show its association with a complete postcranial skeleton, which could not be located in storage.

Three of the 66 are *Non-decapitations*? For these individuals provenience information found with the crania indicated they were part of burials of intact bodies, but the postcranial bones had become separated in storage and could no longer be identified with certainty. Decapitation damage does not appear on these crania.

Four of the 66 are *Non-decapitations*, intact or nearly intact skeletons which exhibit no signs of decapitation.

The remaining 28 crania lack physical or documentary evidence of their archaeological context. Contextual information is also lacking for cranial bones which could not be assigned to any of the 66 groupings.

Since many crania were fragmentary after their years in storage, a methodology for determining sex was developed with the goal of reducing bias to a minimum. Simple presence or absence of 17 traits, eight characteristic of female crania and nine characteristic of male crania (Table 1), according to Bass (1971), were recorded for each individual. No attempt was made to record degree of expression of the traits. As many traits were evaluated as possible, given each individual's state of fragmentation. If eight or more traits could be evaluated and at least 75% of them pointed to one sex the individual was evaluated as *Male* or *Female*. If eight or more traits could be evaluated and 67% to 74% of them pointed to one sex, the individual was evaluated as *Male*? or *Female*?. If between four and seven traits could be evaluated and all of them pointed to one sex, the individual again was evaluated as *Male*? or *Female*?. Using these criteria, 10 crania were identified as Female and 11 were Male, seven were Female?, and 10 were Male?. One additional bone which could not be connected to any of the larger cranial groupings was Female? and another was Male?.

Table 1 Traits used to determine sex for Iximché crania.	
Female traits:	Circular eye orbit
	Sharp upper edge of eye orbit
	Frontal and parietal bossing
	Small, smooth, and gracile
	Thin zygomatic arch
	Low, smooth zygomatic surface
	Small mandible head
	Narrow mandible body at second molar
Male traits:	Prominent supraorbital ridges
	Large frontal sinuses
	Long posterior end of zygomatic
	Large palate
	Large mastoid
	Marked external occipital protuberance
	Large nuchal crests
	Marked eminences on mandibular angle
	Square chin with protuberances

Five crania were determined to have come from *Subadults* (younger than age 15) because of their small, thin bones and the state of their dental development and tooth eruption. Ubelaker's standards (1989:64) for dentition in Amerindians were used for aging subadults. An additional six bones which could not be matched with any of the larger cranial groupings also came from subadults. Eleven crania and six additional bones which could not be connected to any larger groupings had third molars with roots which had not yet completely formed. The best estimate of the ages of these individuals is approximately 15 to 21, and they can be called *Young Adults*. The remaining individuals can only be classified as *Adults* (age 15 or older). The Adult and Young Adult categories overlap. It is likely that some Young Adults are classified as Adults because they lack dentitions, have third molars with incomplete root development hidden within mandibles or maxillas, or had root closure occur at a relatively young age. Despite this, the average age of Young Adults undoubtedly is lower than the average age of Adults. It is clear that the age distribution of this sample does not resemble that of a normal population.

[Table 2](#) is a cross-tabulation showing the number of individual crania classified into different categories of age, sex, and type. The data are much too sparse to allow meaningful statistical analysis of patterns, but a few aspects of the table are worth noting. The characteristics of individuals identified as Decapitations provide some insights into highland warfare and human sacrifice on the eve of the Spanish Conquest. While the majority of victims were males, at least some were females. A large proportion of victims falls into the Young Adult category. It is logical that either captive warriors or non-combatants from settlements within enemy territory chosen for sacrifice would be in the prime of life. Sacatapequez rebels fighting Iximché captured and sacrificed women and children (Borg, n.d.), and a similar practice may explain the presence of female victims at Iximché. However, the females may have been combatants. The *Anales de los Kaqchikeles* (Recinos, 1988:90) indicates that women from Iximché went into battle as warriors at least once.

Table 2
Cross-tabulation of age, sex, and type for Iximché crania.

	Decapitation			Decapitation?			Non-decapitation?			Non-decapitation			Unknown		
	Adult	Young Adult	Sub-adult	Adult	Young Adult	Sub-adult	Adult	Young Adult	Sub-adult	Adult	Young Adult	Sub-adult	Adult	Young Adult	Sub-adult
Male	3	1	0	2	1	0	0	0	0	0	0	0	4	0	0
Male?	4	2	0	2	0	0	0	0	0	0	0	0	2	0	0
Female?	0	2	0	1	0	0	1	0	0	1	0	0	2	0	0
Female	1	1	0	3	2	0	0	0	0	1	0	0	2	0	0
Unknown	2	1	0	2	1	0	1	0	1	0	0	2	16	0	2

All but one of the decapitated individuals have physical evidence on the base of the skull, the vertebrae, or both of the decapitation process. Decapitation must have been a slow, messy process, since the tool of choice was a stone knife or ax with a jagged, almost serrated edge. Decapitation is one of the common forms of sacrifice depicted in Classic period (A.D. 250-900) Maya art (Schele, 1984) and pressure-flaked stone axes and leaf-shaped stone knives frequently appear in painted and sculpted sacrificial scenes throughout Mesoamerica (Boone, 1984). At Iximché, widespread damage typically occurs on the structures of the base of the skull, including the edge of the foramen magnum, the mastoid process, the inferior surface of the occipital, and the posterior angles of the mandible. Vertebrae deposited with the cranium frequently are heavily damaged or even cut completely through. Damage occurs in standardized patterns so that decapitations not positively identified from excavation photos can be tentatively identified. Trauma apparently associated with the process of decapitation occurs on the cranium or vertebrae of 29 of the 66 individuals in the overall sample. It also occurs on 12 mandibles and one temporal which cannot be matched to any of the 66 individuals (Table 3).

Table 3
Decapitation Damage at Iximché.

Identification	Type	Damage Location						
		Mandib. angle	Atlas	Axis	Mastoid	Inf. occip.	Mandib. ramus	Other
IX-2	Decapitation	X						
IX-4	Decapitation	X	X	X	X	X		
IX-5	Decapitation	X	X	X				
IX-6	Decapitation?	X	X	X	P			
IX-7	Decapitation		X	X			X	
IX-9	Decapitation?	X						Inf. body of mand.
IX-10	Decapitation	P	X					
IX-11	Decapitation	X	X		P			
IX-12	Decapitation	X			X			
IX-13	Decapitation	X	X	X				
IX-16	Decapitation	X	X		P			
IX-19	Decapitation	X	X					
IX-20	Decapitation	X	X					
IX-21	Decapitation	X	X		P	P		
IX-22	Decapitation	X			P			Occip.condyle (poss.)
IX-23	Decapitation?	X			P	X		
IX-28	Decapitation?	X				P		
IX-29	Decapitation?	X						
IX-33	Decapitation			X				Third cervical vert.
IX-40	Decapitation?		X	X	X			
IX-41	Decapitation	X						
IX-43	Decapitation?	X						
IX-46	Decapitation	X						
IX-47	Decapitation?	X						
IX-50	Decapitation?	X						
IX-51	Decapitation?	X			P			
IX-52	Decapitation?	X			P			
IX-53	Decapitation							
IX-54	Decapitation?	X	X	X				
IX-56	Decapitation?			X				
IX-68	Decapitation?			P				
50-iii	Decapitation?	X						

106	Decapitation?	X						
176#1	Decapitation?						X*	
176#2	Decapitation?	X						
206-N	Decapitation?	X						
229#8	Decapitation?				X*			
263	Decapitation?	X						
270-i	Decapitation?	X*						
270-ii	Decapitation?	X						
Str. 39-i	Decapitation?	X						
Str. 39-iii	Decapitation?	X						
Str. 45-ii	Decapitation?	X						
Str. 45-iii	Decapitation?	X						
X = Present P = Possible * = Thin, straight cuts								

David Reed subjected 18 human ribs and a dog mandible from Iximché to stable isotope analysis at the Mass Spectrometry Laboratory at Penn State University. Analysis of stable isotopes of carbon and nitrogen in the non-mineral portion of bone, called collagen, can be used to infer diet (DeNiro and Epstein, 1978; 1981). The turn-over of stable isotopes in bones means that they reflect the diet during the last few years before death. Preliminary results for Iximché have been published previously (Whittington and Reed, 1994; 1998). A summary of these publications follows, along with final results, with minor corrections, as presented by Reed and Whittington (1995) and Whittington *et al.* (1996).

Measures of isotopic composition of a material are expressed in per mil (‰) as the deviation, or delta (d), of the ratio of heavy to light isotopes in the sample from the ratio in a reference sample. Isotopic ratios can be related to terrestrial plants or marine sources (DeNiro, 1987). Terrestrial plants can be divided into three types, based on type of photosynthesis, each with its own carbon isotopic signature (Coleman and Fry, 1991). C3 plants are leafy and include legumes, while C4 plants are tropical grasses such as maize. Stable isotope analysis of carbon and nitrogen in skeletal tissues may be used to differentiate between the consumption of C3 and C4 plants (with average carbon isotope ratios of -26‰ and -12‰ respectively), and between terrestrial and marine diets (the latter with enriched isotope ratios in both C and N) (Ambrose, 1993). Experimental studies using rats fed isotopically-controlled diets have shown that bone collagen, the non-mineral portion of bone, is produced primarily from protein components of the diet (at least when the overall diet contains sufficient protein). Isotopic signatures, together with paleobotanical, paleopathological, and social interpretations derived from the archaeological record, provide a direct method of determining diet.

In Guatemala, Reed sorted all ribs found together in each storage bag by morphology, preservation, size, side, and location within the rib cage. He preferentially chose fragments of the first rib for analysis, in an attempt to avoid sampling individuals twice. When a skeleton that appeared not to have been sampled had no first rib, he took fragments of another rib. He also took a fragment of the mandible of a dog to compare the diet of a domesticated animal.

After analysis at Penn State, he discarded the results for five of the rib samples, three because they may have been from previously sampled individuals and two because they were extreme outliers. The latter two samples might represent some subgroup, but the individuals share no obvious social, demographic, or pathological characteristics. For the remaining 13 human ribs, the mean value for nitrogen is 7.9‰ and the mean value for carbon is -7.8‰ (Table 4).

Table 4
Results of analyses of stable isotopes in bones from Iximché.*

Identification	$d^{13}C$	$d^{15}N$	Notes
IX-1	-8.80	7.61	Right rib
IX-24	-7.39	8.29	Subadult right rib
IX-34	-7.56	8.07	Rib
IX-69	-5.99	10.72	Subadult ribs. Extreme
GO	-7.77	8.61	Ribs
GP	-7.70	6.88	Subadult rib
50-i	-7.66	7.21	Rib
50-ii	-8.12	8.28	Rib
129-i	-7.99	7.92	Right rib
129-ii	-8.01	7.87	Left rib. Duplicate?
224-i	-7.52	7.83	First left rib
224-ii	-7.72	7.42	First right rib
224-iii	-8.11	7.60	Right rib. Duplicate?
224-iv	-8.37	7.55	Rib. Duplicate?
229-i	-6.30	3.76	First left rib. Extreme
229-ii	-8.53	7.93	First left rib
229-iii	-9.29	9.17	First right rib
263	-7.67	8.37	Rib
229	-6.13	7.42	Dog mandible

*Data from Reed and Whittington (1995).

Wright and White (1996) summarized isotopic composition of human collagen at 14 Maya sites, including Iximché. The mean nitrogen value for Iximché is low in comparison to most other sites, except Itzán and Copán. The mean nitrogen isotope value indicates that the highlanders buried at Iximché ate an exclusively terrestrial diet, while residents of some other sites included a marine animal component in their diets. The mean carbon isotope value at Iximché is similar to values for people who eat a diet composed of a high proportion of maize. The specimens from Iximché have a more positive mean carbon isotope ratio than any other site presented by Wright and White. This probably reflects not only dietary differences between the sites, but also Iximché's 2200 m altitude, higher than any other Maya site yet sampled. Researchers have observed that the carbon isotope composition of plants shifts toward less negative values with increasing altitude (Körner *et al*., 1988; Marino and McElroy, 1991; Polley *et al*., 1993).

Description of Current Project

FAMSI awarded Whittington a $2500 grant to permit Robert H. Tykot of the University of South Florida to perform stable carbon isotope analyses of 43 human teeth from Iximché in 1999. Tykot *et al*. (2000) summarized the project and presented the results.

Most of the teeth came from individuals with morphological evidence of decapitation, and usually from crania which cannot be matched with specific postcranial remains. These individuals are likely to be either sacrificial victims or captives from surrounding enemy groups. Dietary analysis was performed in order to investigate the possibility that local dietary variation may have existed among Late Postclassic settlements (according to variations in local ecology), and also between members of different social classes (e.g. high-status captives). All of the teeth are third molars, for which the crown is typically formed between the ages of 9 and 12. The diets represented in the teeth are therefore juvenile, but long past weaning, and are expected to be similar to adult diets unless significant changes in status or residence location has occurred. The tooth data reported here complement analyses of human bone from the same collection.

In contrast to bone collagen, the carbon isotope ratio of bone apatite, a crystalline mineral, is consistently representative of the whole diet (Ambrose and Norr, 1993). Tooth enamel is structurally similar to bone apatite, but after tooth formation is not subject to continuing replacement as are bone collagen and apatite. The dietary information recorded in tooth enamel therefore reflects diet at the age of tooth formation regardless of the age at death of the individual.

The reconstruction of dietary patterns depends on the identification of a combination of protein, carbohydrate, and lipid food resources which could produce specific bone isotope ratios. The most successful dietary reconstructions will occur in areas where the potential food resources are well-known from the archaeological remains, are well-characterized isotopically, and where specific resources will have unique isotopic values (e.g. maize or marine resources in otherwise C3-based ecological systems). Regardless of the specificity of the dietary reconstruction, variation based on geographic, chronological, status, or sex differences may be easily demonstrated.

Analytical Procedures

Analyses of enamel from 43 teeth were done at the University of South Florida. Enamel powder was carefully removed from each tooth using a diamond-tipped dental drill in order to minimize the destructive nature of sample removal. Relatively large samples were taken, penetrating through all enamel layers, in order to avoid variations in isotope ratios found in small samples, which result from seasonal variations in diet. Residual organic content of the tooth enamel powder was removed using sodium hypochlorite, while buffered acetic acid was used to remove non-biogenic and adsorbed carbonates. Laboratory experiments have shown this to be a reliable method of sample preparation (Koch *et al*., 1977; Tykot, unpublished data). Carbon dioxide was released from the tooth enamel powder by reaction with 100% phosphoric acid in an individual acid bath autosampler, and measured on an isotope ratio mass spectrometer. The precision of all analyses is about 0.1‰, and is based on replicate analyses of working standards and international reference materials. Isotope ratios are reported using the delta notation (d), relative to the Cretaceous Pee Dee Belemnite formation for carbon and ambient air for nitrogen.

Results

The 43 samples tested range in $d^{13}C$ values from -5.2‰ to +0.1‰, with a mean of -2.1±1.1‰, a large spread for a population representing at most a couple of generations (Table 5). Several individuals (IX-2, IX-4, XP-60, XP-62, XP-63), three of which are Decapitations, stand out as having carbon isotope values substantially different than the average, suggesting substantially different dietary patterns, at least at the age of tooth formation. Some or all of these individuals likely grew up at sites other than Iximché, and at least the three with the most negative carbon isotope ratios (-4.3, -5.0, -5.2) either came from areas with more abundant C3-based food resources, or they were elites from other communities who had differential access to alternative foods because of their ascribed status.

Table 5
Results of analyses of stable isotopes in teeth from Iximché.

Lab ID	Identification	Type	Sex	Age	$d^{13}C$
usf-431	IX-1	Non-decapitation	Female	Adult	-2.04
usf-432	IX-2	Decapitation	Male?	Adult	0.08
usf-433	IX-4	Decapitation	Male?	Adult	-4.28

usf-434	IX-5	Decapitation	Male	Young adult	-0.85
usf-435	IX-6	Decapitation?	Female	Young adult	-2.21
usf-437	IX-7	Decapitation	Male?	Young adult	-2.17
usf-438	IX-8-i			Adult	-1.76
usf-439	IX-9	Decapitation?	Female?	Adult	-1.88
usf-440	IX-10	Decapitation	Male	Adult	-2.21
usf-441	IX-11	Decapitation	Female?	Young adult	-1.94
usf-442	IX-12	Decapitation	Female	Adult	-2.02
usf-443	IX-13	Decapitation	Male	Adult	-2.25
usf-448	IX-15		Female?	Young adult	-3.25
usf-449	IX-16	Decapitation	Male?	Adult	-3.07
usf-450	IX-17	Non-decapitation?		Adult	-2.44
usf-451	IX-18			Adult	-2.47
usf-452	IX-19	Decapitation		Young adult	-0.93
usf-444	IX-20	Decapitation	Male?	Adult	-0.83
usf-445	IX-21	Decapitation	Male?	Young adult	-1.94
usf-446	IX-22	Decapitation		Adult	-1.64
usf-447	IX-23	Decapitation?	Female	Adult	-2.02
usf-453	XP-46	Decapitation?		Adult	-1.84
usf-454	XP-47			Adult	-2.34
usf-455	XP-48	Decapitation?		Young adult	-3.20
usf-456	XP-49			Young adult	-3.45
usf-457	XP-50			Young adult	-2.31
usf-458	XP-51	Decapitation?	Male?	Adult	-1.48
usf-459	XP-52	Decapitation?		Adult	-1.43
usf-460	XP-53	Decapitation?		Adult	-2.23
usf-461	XP-54			Adult	-1.80
usf-462	XP-55	Decapitation?		Adult	-1.32
usf-463	XP-56	Decapitation?	Female	Young adult	-0.66
usf-464	XP-57	Decapitation?	Male?	Adult	-1.09
usf-465	XP-58	Decapitation?	Male	Young adult	-2.25
usf-466	XP-59	Decapitation?		Adult	-2.90
usf-467	XP-60	Decapitation	Female	Young adult	-0.31
usf-468	XP-61	Decapitation	Female?	Young adult	-2.40
usf-469	XP-62			Adult	-4.98

usf-470	XP-63	Decapitation?		Adult	-5.19
usf-471	XP-64	Decapitation?		Young adult	-1.57
usf-472	XP-65	Decapitation?	Male	Adult	-1.65
usf-473	XP-66	Decapitation?	Male	Adult	-1.46
usf-436	XP-67	Decapitation	Male	Adult	-3.72

Too few individuals without evidence of decapitation were tested to compare Decapitations and Non-decapitations statistically. The few results available for the latter all fall within the range of variation for Decapitations, but it is not known whether they are representative of the Iximché residential population. There are however some noticeable, if not statistically significant, differences between Females (mean=-1.5; n=6) and Males (mean=-2.1; n=7). The greater homogeneity of the carbon isotope ratios in females (range=1.9) suggests that much of the overall dietary variation seen at Iximché comes from males (range=2.9), who would be more likely than females to come from other ecological settings as war captives and/or to have differential access through higher status to a variety of food resources.

Given the chronology and location of Iximché, the degree of consumption of maize is likely to account for most of the variation in stable carbon isotope ratios in tooth enamel. Without the establishment of baseline isotopic values for the specific fauna and flora likely to have been consumed by the Kaqchikel and their neighbors, it is not possible to estimate precisely the importance of maize in the diet. Using theoretical endpoints of about -14‰ and +2‰ in apatite, respectively, for pure C3 and pure C4 diets, maize, or maize-fed animals, contributed on the order of 75-85% of the whole diet at the time of tooth formation. This interpretation is consistent with that based on the bone collagen analyses (Whittington and Reed, 1994; 1998), which indicate that the protein portion of the diet (both adult and juvenile) was derived primarily from maize, which is actually quite poor in protein content. Based on experimental data produced by Ambrose and Norr (1993), the average carbon isotope value of the foods consumed at Iximché is estimated at -11.6‰. With maize averaging about -9.5‰ (Schwarcz *et al*., 1985; Wright, 1994), the consumption of C3 plants and wild animals (with $d^{13}C$ values of -26‰ to -19‰) could only have been a minor part of the diet of the individuals recovered at Iximché. Diets at or near Iximché were different from all other Maya sites for which stable isotope data are available. In comparison to Postclassic Lamanai in Belize, and several Classic period sites in the Petén region of Guatemala (Wright and White, 1996; van der Merwe *et al*., n.d.), it appears that those buried at Iximché were dependent on maize to a greater degree.

Conclusion

Substantial variation in carbon isotope ratios were observed in the analyzed sample of 43 teeth from Iximché, with all individuals exhibiting very heavy reliance on C4 plants, most likely maize. Several individuals had substantially different diets at the time of tooth formation, in all but one case relying on substantially less maize in the diet. At minimum this suggests the availability of alternative food resources, but it cannot be determined at this time whether this is due to short-term dietary variation during the time of tooth formation; living in different ecological settings; or preferential access based on elite status to alternative food resources, such as domesticated C3 crops or hunted animals. Analysis of multiple teeth from the same individual, combined with the correlation of isotopic results for tooth enamel samples with bone collagen from the same individual would help to resolve this issue. A study of the isotopic ecology of the Iximché region would also permit more precise estimation of the importance of specific food groups to Iximché diets.

Sources Cited

Ambrose, S.H.
1993 Isotopic Analysis of Paleodiets: Methodological and Interpretive Considerations. In*Investigations of Ancient Human Tissue: Chemical Analyses in Anthropology,* edited by M.K. Sandford, pp. 59-130. Gordon and Breach, Amsterdam.

Ambrose, S.H., and L. Norr
1993 Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate. In *Prehistoric Human Bone: Archaeology at the Molecular Level,* edited by J. Lambert and G. Grupe, pp. 1-37. Springer-Verlag, Berlin.

Bass, W.M.
1971 Human Osteology: A Laboratory and Field Manual of the Human Skeleton. Missouri Archaeological Society, Columbia.

Boone, E.H.
1984 Ritual Human Sacrifice in Mesoamerica. Dumbarton Oaks, Washington.

Borg, B.
n.d. Cakchikel Postclassic Origins. Manuscript in possession of the authors.

Coleman, D.C., and B. Fry
1991 *Carbon Isotope Techniques.* Academic Press, San Diego.

DeNiro, M.J.
1987 Stable Isotopy and Archaeology. *American Scientist* 75:182-191.

DeNiro, M.J., and S. Epstein

1978 Influence of Diet on the Distribution of Carbon Isotopes in Animals. *Geochmica et Cosmochimica Acta* 42:495-506.

DeNiro, M.J., and S. Epstein

1981 Influence of Diet on the Distribution of Nitrogen Isotopes in Animals. *Geochimica et Cosmochimica Acta* 45:341-351.

Guillemin, G.F.

1969 Exploration du Groupe C d'Iximché (Guatemala). *Bulletin de la Société suisse des Américanistes* 33:23-33.

Guillemin, G.F.

1977 Urbanism and Hierarchy at Iximché. In *Social Process in Maya Prehistory: Studies in Honor of Sir Eric Thompson,* edited by N. Hammond, pp. 227-264. Academic Press, London.

Koch, P.L., N. Tuross, and M.L. Fogel

1997 The Effects of Sample Treatment and Diagenesis on the Isotopic Integrity of Carbonate in Biogenic Hydroxylapatite. *Journal of Archaeological Science* 24:417-429.

Körner, Ch., G.D. Farquhar, and Z. Roksandic

1988 A Global Survey of Carbon Isotope Discrimination in Plants from High Altitude.*Oecologia* 74:623-632.

Marino, B.D., and M.B. McElroy

1991 Isotopic Composition of Atmospheric CO_2 Inferred from Carbon in C_4 Plant Cellulose.*Nature* 349:127-131.

Polley, H.W., H.B. Johnson, B.D. Marino, and H.S. Mayeux

1993 Increase in C_3 Plant Water-Use Efficiency and Biomass over Glacial to Present CO_2Concentrations. *Nature* 361:61-64.

Recinos, A.

1988 Memorial de Sololá, Anales de los Kaqchikeles, Título de los Señores de Totonicapán.Editorial Piedra Santa, Guatemala.

Reed, D.M., and S.L. Whittington

1995 *El análisis de isótopos estables de carbono y nitrógeno en los huesos de Iximché.*Final technical report submitted to Instituto de Antropología e Historia, Guatemala.

Schele, L.
1984 Human Sacrifice among the Classic Maya. In *Ritual Human Sacrifice in Mesoamerica,* edited by E.H. Boone, pp. 7-48. Dumbarton Oaks, Washington.

Schwarcz, H.P., J. Melbye, M.A. Katzenberg, and M. Knyf
1985 Stable Isotopes in Human Skeletons of Southern Ontario: Reconstructing Paleodiet. *Journal of Archaeological Science* 12:187-206.

Tykot, R.H., S.L. Whittington, D.M. Reed, and J.W. Wilson
2000 Diet, Demography, and Decapitation in the Late Postclassic: Stable Isotope Analysis of Human Teeth from Iximché, Guatemala. Paper presented at the 65th Annual Meeting of the Society for American Archaeology, Philadelphia.

Ubelaker, D.H.
1978 *Human Skeletal Remains.* Manuals on Archaeology 2. Taraxacum, Washington.

van der Merwe, N.J., R.H, Tykot, N. Hammond, and K. Oakberg
n.d. Diet and Animal Husbandry of the Preclassic Maya at Cuello, Belize. In *Close to the Bone: Biogeochemical Approaches to Paleodietary Analysis in Archaeology,* edited by S. Ambrose and A. Katzenberg. Advances in Archaeological and Museum Science Series. Plenum, New York. In press.

Whittington, S.L., and D.M. Reed
1994 Los esqueletos de Iximché. In *VII Simposio de Investigacions Arqueológicas en Guatemala, 1993,* edited by J.P. Laporte and H.L. Escobedo, pp. 23-28. Museo Nacional de Arqueología y Etnología, Guatemala.

1998 Evidencia de dieta y salud en los esqueletos de Iximché. *Mesoamérica* 35:73-82.

Whittington, S.L., D.M. Reed, D.A. Merriwether, and B. Adams
1996 Rescue Osteology: Salvaging the Past at Iximché, Guatemala. Paper presented at the 61st Annual Meeting of the Society for American Archaeology, New Orleans.

White, C.D., M.W. Spence, H. Le Q. Stuart-Williams, and H.P. Schwarcz
1998 Oxygen Isotopes and the Identification of Geographical Origins: The Valley of Oaxaca versus the Valley of México. *Journal of Archaeological Science* 25:643-655.

Wright, L.E.
1994 The Sacrifice of the Earth? Diet, Health, and Inequality in the Pasión Maya Lowlands.Unpublished Ph.D. dissertation, University of Chicago, Chicago.

Wright, L.E., and C.D. White
1996 Human Biology in the Classic Maya Collapse: Evidence from Paleopathology and Paleodiet. *Journal of World Prehistory* 10:147-198.