Description of Studies
Kennewick Man Skeleton
February 2006 Study Session
Paper dated: January 26, 2006

This paper describes the studies and procedures that will be used for examining the Kennewick Man skeleton during the study session that has been scheduled for February 2006. This session follows earlier examinations of the skeleton by plaintiffs' representatives in December 2004 (condition and facilities inspection) and July 2005 (taphonomic evaluation). Both of those examinations were important and productive. They established essential baseline data about the skeleton, and provided information critical for planning the studies to be conducted during the forthcoming session. Future investigators will be materially aided by the image record that was created and by the casts that were made of the skull, hip and embedded projectile point.

The purpose of the February 2006 study session is to build upon and augment the information that has been obtained to date by plaintiffs' representatives and prior investigators. More specifically, plaintiffs' study team during this session will focus on the following tasks: (a) expanding the image record; (b) verifying the accuracy of the casts;(c) obtaining supplementary taphonomic data; (d) checking data reported by prior investigators; (e) obtaining data not previously recorded.

I. Work Schedule

Wednesday, February 15

Doug Owsley and *Kate Spradley* arrive in Seattle.

Thursday, February 16

Morning: *Richard Jantz* arrives in Seattle

Morning -Afternoon: Burke small lab

Owsley, Jantz, Spradley:
Preparation of bones for radiography – application of parafilm to humeri, radii, ulnae, femora, tibiae

Bones are packaged for transport to a local facility for CT and radiography with direct involvement by the conservators and COE staff. As before, we would appreciate being able to use parafilm provided by the conservators.

3D cranial measurements (equipment assembly and verification of proper function)

Bart Cannon:
Brief visit to the Burke Museum to determine feasibility of electron microprobe analysis of the embedded projectile point

Troy Case:
Examination of hand and foot bones as described in plaintiffs' October 10, 2002 Study Plan. Note: the time schedule for his examination is being confirmed; the target dates are February 16-17 or February 23-24. Dr. Case is currently working at a remote site in Thailand. We are in occasional email contact with him, and he will be back in the U.S. on February 1st. His study schedule will be finalized as soon as possible.

Friday, February 17 (Burke small lab)

Jantz and *Spradley:*
3D cranial measurements

Owsley, Jantz, Spradley:
Transport to local radiographic facility for standard radiography of the dentition (to assess dental pathology and traits) and specific bones (for paleopathology) and CT of long bones. The following elements are requested: maxillae, mandible, humeri, radii, ulnae, femora, tibiae, right ilium fragment with the embedded projectile point, selected rib fragments with pinched ends and comparative fragments with normal ends; glenoid portion of the right scapula, and a few vertebrae. Specific facility arrangements are being scheduled and will be forwarded to the Corps after final confirmation. Direct involvement by COE staff is requested.

In the morning, the right ilium fragment transported to Cannon Microprobe (1041 NE 100th Street, Seattle) for elemental analysis using X-ray fluorescence and the electron microprobe. The specific time will be arranged so as not to conflict with radiography. Direct involvement by COE staff is requested.

Saturday, February 18 - Monday, February 20 Burke closed

Monday, February 20

Chip Clark, George Gill, Hugh Berryman, Tom Stafford, and Cleone Hawkinson arrive in Seattle.

Tuesday, February 21 (Burke classroom)

Owsley, Berryman and Stafford, note taking by C. Hawkinson:
Taphonomic assessment of the cranium and mandible and resolution of specific vertebral column and long bone questions developed during review of notes following the taphonomy study session.

Owsley, note taking by Hawkinson:
Bone and dental pathology - assessment of the cranium and mandible.

Clark:
Photography - specific images identified during review of notes following the taphonomy study session, team photography.

Photographic documentation of R. Jantz and K. Spradley using the 3D digitizer.

G. Gill:
Collects osteological data following his system.

Wednesday, Feb 22 (Burke classroom)

Owsley, Berryman and Stafford, note taking by C. Hawkinson:
Taphonomic assessment of the cranium and mandible and resolution of specific vertebral column and long bone questions developed during review of notes following the taphonomy study session [continuation].

Owsley, note taking by Hawkinson:
Bone and dental pathology - assessment of the cranium, mandible and specific skeletal elements [continuation].

Clark:
Photography - specific images identified during review of notes following the taphonomy study session, team photography [continuation].

G. Gill:
Collects osteological data following his system [continuation].

Berryman, Gill and Owsley:
Aging: Discussion of aging criteria.

Della Cook:
Collects paleopathology observations.

Jim Chatters:
Pathology, functional morphology, and consultation/discussion with team members.

Clark:
Team photography.

Thursday, Feb 23 (Burke small lab)

C. Hawkinson:
Liaison between scientists and Corps personnel.

Della Cook:
Collects paleopathology observations [continuation, and consultation with C. Loring Brace].

Jim Chatters:
Pathology, functional morphology, and consultation/discussion with team members [continuation].

Brace team - C. Loring Brace, Russell Nelson, Noriko Seguchi, and Daris Swindler:
Cranial metrics, dental metrics, dental wear and occlusion, dental discrete traits.

Clark:
Available for team photography.

Friday Feb 24 (Burke small lab)

C. Hawkinson:
Liaison between scientists and Corps personnel.

Mark Teaford:
Preparation of high resolution dental impressions.

Benjamin Auerbach:
Collection of postcranial measurements to be used in evaluating body size and shape.

Clark:
Available for team photography.

II. Supplemental Information on Data Collection

The following is a supplement to the information contained in plaintiffs' October 10, 2002 Study Plan.

Benjamin Auerbach, Ph.D. candidate, Johns Hopkins University

Description: The primary goal of Auerbach's research is the examination of body size and shape characteristics of geographically and temporally diverse samples of prehistoric New World populations. These characteristics will be used to determine whether climatic and subsistence factors significantly affect morphological phenotypes (and thus variation) in the New World. Results, in turn, will inform New World population origin models. New and recently developed techniques for reconstructing stature and body mass will be applied to archaeological samples to explore this variation; resulting methodologies will also be made available to other researchers. Understanding the development of morphological diversity in the Americas will aid in the interpretation of patterns of morphological variation throughout the world, including those associated with any of the major human geographic dispersals during the Pleistocene.

The osteometrics to be used in this study are listed below, with associated measurement tools. Dimensions are chosen to assess variation in shape, size and proportions, i.e., basic cranial shape and size, limb bone lengths and diameters, and torso height and breadth. Though most are common measures, some were newly revised in a recently-developed clarification of the Fully anatomical stature estimation technique (Raxter et al., in press), in which Auerbach has been actively involved. Other measurements have recently been reexamined for their accuracy in representing body mass (Auerbach and Ruff, 2004; Ruff et al., 2005). All limb measurements are taken bilaterally when possible and averaged for analysis to minimize the effects of asymmetry arising from activity differences among populations (Auerbach and Ruff, in press). These measures are then used to derive body morphologies, such as body mass, stature, intralimb proportions, relative limb lengths, and cranial proportions.

The inclusion of the oldest American skeletons is crucial to this study. Paleoamerican remains are necessary for interpreting early New World diversity and to provide a comparative basis for the morphologies of later populations. The Horn Shelter, Wilson-Leonard Woman, Whitewater Draw, Spirit Cave, Wizards Beach, Lagoa Santa, Santana do Riacho and other Paleoamerican remains are planned to be included in this study in addition to Kennewick Man. Kennewick Man is unique among the oldest remains in North America, given the good preservation of his skeleton. Such completeness will allow more of the measurements listed below, and thus the derivation of more morphologies. These, in turn, will help inform the kind of climate in which Kennewick Man lived, especially when his body size, shape and proportions are compared with those of a diverse sample of Native Americans from various climates and subsistence strategies. Examination of his body mass and stature using these methods will further refine our understanding of Kennewick Man's physical appearance and how that compares with other ancient inhabitants of the Americas.

Equipment: Most measurements are taken using a Mitutoyo Digital sliding calipers linked to a laptop computer using a digital input device. In addition, a travel osteometric board and spreading calipers, both made by Paleo-Tech Concepts, are used. All measurements are taken when possible and are non-invasive. Auerbach has already taken these measures on more than 1200 skeletons, including the Horn Shelter I and La Jolla Paleoamerican remains. The specific measurements are listed in the following table.

Measurements

Element	Measure[1]	Instrument
Cranium	Basion-bregma	Spreading calipers
	Glabella-opisthocranion	Spreading calipers
	Euryon-euryon	Spreading calipers
	Prosthion-glabella	Sliding calipers
	Rhinion-nasion	Sliding calipers
	Alare-alare	Sliding calipers
	Zygion-zygion	Spreading calipers
Manubrium	Bi-clavicular notch breadth	Sliding calipers
Clavicle*	Maximum length	Osteometric board
	Mid-diaphyseal SI diameter	Sliding calipers
	Mid-diaphyseal AP diameter	Sliding calipers
Humerus*	Maximum length	Osteometric board
	SI head diameter	Sliding calipers
	Mid-diaphyseal AP diameter	Sliding calipers
	Mid-diaphyseal ML diameter	Sliding calipers
	Distal ML epicondylar diameter	Osteometric board
	ML trochlear-capitular diameter	Sliding calipers
Radius*	Maximum length	Osteometric board
	ML head diameter	Sliding calipers
	AP head diameter	Sliding calipers
	Mid-diaphyseal AP diameter	Sliding calipers
	Mid-diaphyseal ML diameter	Sliding calipers
	Distal ML articular diameter	Sliding calipers
Ulna*	Maximum length	Osteometric board
	Mid-diaphyseal AP diameter	Sliding calipers

	Mid-diaphyseal ML diameter	Sliding calipers
Vertebrae (C1-L5 or L6)	Anterior maximum height of vertebrae**	Sliding calipers
	Anterior midline height of vertebrae	Sliding calipers
Sacrum	Anterior maximum height of S1	Sliding calipers
	Maximum anterior sacral length	Sliding calipers
Os coxae	Bi-iliac breadth	Osteometric board
	Maximum iliac blade breadth*	Spreading calipers
	SI acetabular height*	Sliding calipers
Femur*	Maximum length	Osteometric board
	Physiological length	Osteometric board
	AP head diameter	Sliding calipers
	Mid-diaphyseal AP diameter	Sliding calipers
	Mid-diaphyseal ML diameter	Sliding calipers
	Distal ML epicondylar diameter	Osteometric board
	Distal ML articular diameter	Sliding calipers
Tibia*	Maximum length	Osteometric board
	Physiological ("Fully") length**	Osteometric board
	ML proximal plateau breadth	Osteometric board
	ML proximal articular diameter	Sliding calipers
	Mid-diaphyseal AP diameter	Sliding calipers
	Mid-diaphyseal ML diameter	Sliding calipers
	ML & AP distal articular diameters	Sliding calipers
Fibula*	Maximum length	Osteometric board
Tarsals*	Talo-calcaneal height**	Osteometric board
	ML talus trochlear breadth	Sliding calipers

* Measures are taken bilaterally when possible.

**New measurement (Raxter et al., in press)

[1] Planes of measure are abbreviated: SI, superior-inferior; AP, anterior-posterior; ML, medio-lateral.

References:

Auerbach BM, and Ruff CB. 2004. Human body mass estimation: a comparison of "morphometric" and "mechanical" methods. American Journal of Physical Anthropology *125:*331-342.

Auerbach BM, and Ruff CB. in press. Limb bone bilateral asymmetry in modern humans: implications for environmental and genetic influences. Journal of Human Evolution.

Raxter MH, Auerbach BM, and Ruff CB. in press. A new analysis of the Fully Technique for estimating statures. American Journal of Physical Anthropology.

Ruff CB, Niskanen M, Junno J-A, and Jamison P. 2005. Body mass prediction from stature and bi-iliac breadth in two high latitude populations, with application to earlier higher latitude humans. Journal of Human Evolution *48:*381-392.

Richard Jantz, Professor, University of Tennessee

Cranial Coordinates, Measurements and Observations

Description: Three dimensional coordinate data of the cranium will be collected using an electronic digitizer to record the x, y and z coordinates of each point touched. These data will be supplemented with measurements taken by hand instruments for those areas of the cranium (such as the mandible) not adequately measured by the digitizer. Observations of discrete traits and other characteristics also will be recorded.

Coordinate data will be obtained from a reconstructed cast, in the presence of the actual cranial bones of Kennewick man. The cast has the advantage that it has been permanently reconstructed. Accuracy of the cast will be checked against the original.

Responsible Scientists: The data collection will be performed by Dr. Richard Jantz. Assisting him will be Kate Spradley, PhD student.

Purpose: Dr. Jantz and his colleague Dr. Owsley have compiled a database containing cranial measurements and observations on more than 7000 modern and prehistoric individuals. This database allows researchers to discriminate between populations in time and space. Morphological measurements and observations on the Kennewick Man skeleton will provide similar insights into population relationships for this individual. Measuring techniques are noninvasive and will not cause damage to the skeleton. This data will be used to identify the morphometric relationships of Kennewick Man to other early crania, later crania in America and other parts of the world. Questions have been raised about the accuracy of some of the cranial measurements taken by prior investigators. Those measurements are the only data available to the scientific community and are already being used by others in analyses of the skeleton. It is essential that they be verified, and if necessary corrected. In addition, coordinate data have not been obtained from the Kennewick cranium. Coordinate data provide much finer characterization of morphology and allow explicit comparisons of shape. It is also possible to increase visual appreciation of variation by using wire frame models of skulls obtained by connecting landmarks. Coordinate data also allow computation of non-standard measurements, which may provide greater insights into variation among early American crania and between early and later American crania.

Equipment: The following equipment and materials will be used: sliding calipers, spreading calipers, coordinate calipers, radiometer, recording forms, pencil, latex gloves, digitizer, and laptop computer.

Precedents: Taking standard measurements has been an accepted scientific practice for several generations. For the past 20 years, Dr. Jantz has utilized measurements that are expanded slightly from Howells' (1973) classic and highly influential work. Although dating to the early 20th century in concept, the extensive collection of coordinate data is little more than a decade old and has been made possible by the availability of affordable and portable digitizers (see Rohlf and Marcus 1993). Dr. Jantz has used his measurement techniques on numerous collections under the jurisdiction of the Bureau of Land Management, Bureau of Reclamation, U.S. Army Corps of Engineers, and on important early American crania, including Wizards Beach, Spirit Cave (BLM), Horn Shelter, Gordon Creek (Forest Service), and Arch Lake. He has also used these techniques to evaluate recent and ancient specimens from other parts of the world. Ancient remains examined include Mladec 1 from the Eastern European Upper Paleolithic, various Mesolithic Norwegians, and a collection from the Nubian Epipaleolithic. These techniques are frequently used in forensic identification and in assisting in tribal identification for NAGPRA claims. The value of morphometric data for testing hypotheses about peopling of the New World is demonstrated in Jantz and Owsley (in press).

Comparison with Other Data Sets: Dr. Jantz's three-dimensional measurement methodology and his comparative data set, based on the Howells' system, differ substantially from the measurements and techniques standard to Dr. Gill's protocol, which places heavy emphasis on a simometer caliper. Equally unique is Dr. Brace's measurement system that he has followed for more than thirty years. Brace's large comparative data set of more than 10,000 individuals contains extensive Old World population representation, including a large prehistoric Japanese series. Drs. Russell Nelson and Norico Seguchi will help Dr. Brace record his data set. Dr. Seguchi will be taking dental measurements for comparison with data collected for her dissertation, which was a study of dental metrics of past and present Japanese. Dr. Swindler is Professor of Anthropology emeritus at the University of Washington. He is a distinguished dental anthropologist with an extensive publication record.

Richard Jantz

Postcranial Measurements

Description: Measurements will be taken and recorded of the postcranial skeleton. The measurements to be taken are similar to those described in Moore-Jansen et al (1994) and Buikstra and Ubelaker (1994). In addition to standard measurements, vertebral heights and articulated talus and calcaneus heights are required for anatomical estimation of stature.

Responsible Scientists: The data collection will be performed by Dr. Richard Jantz. Assisting him as recorder will be Kate Spradley, Ph.D. student.

Purpose: The postcranial measurements will allow assessment of limb proportions, skeletal size and robusticity. These data will be compared to the existing database of measurements compiled by Drs. Jantz and Owsley for other skeletal remains. This database includes both early and recent Americans. The comparisons will lead to interpretations of adaptation (limb proportions) and activity patterns (size and shape of long bone shaft dimensions). Postcranial dimensions also will be used as a body size control to examine variations in cranial size. Anatomical estimation of stature will provide a more accurate estimate than can be obtained using long bone regression equations. At the present time, the only measurements of the Kennewick Man postcranial skeleton available to the scientific community have not been independently corroborated. In addition, Dr. Jantz' measurement protocol differs somewhat from those used by prior investigators. Certain postcranial measurements are particularly difficult to take, and it is important that Dr. Jantz obtain Kennewick Man skeletal data that are comparable to other data in his database. It is also important that the record developed for this skeleton be as complete and accurate as possible under current techniques. Together with the image record to be made of the skeleton, the postcranial measurements will allow future scientists to study Kennewick Man's morphology. It has been demonstrated recently that traditional postcranial data are closely related to long bone shaft cross-sectional properties as seen on actual cross sections or CT scans (Wescott 2001). The information obtained during plaintiffs' study session will allow broad comparisons of Kennewick Man's functional morphology.

Equipment: This protocol will involve use of the same equipment and materials as described in the section entitled "Cranial Coordinates, Measurements and Observations."

Precedents: Postcranial measurements are an accepted and recommended scientific procedure (Moore-Jensen 1994; Buikstra and Ubelaker 1994). Dr. Jantz has collected such measurements on numerous collections held by federal agencies, including those under the jurisdiction of the Bureau of Land Management, Bureau of Reclamation and U.S. Army Corps of Engineers. He has gathered such data for a number of important early American postcrania, including Wizards Beach, Spirit Cave (BLM), Horn Shelter, Gordon Creek (Forest Service), and Arch Lake.

Long Bone Shaft Cross-sectional Properties

Description: The femora, tibiae, humeri, radii and ulnae will be CT-scanned at a local CT-scanning facility. It is our intention to scan complete bones or fragments thereof with 1 mm slices or less, depending on the capability of the equipment. This will necessitate transporting the bones from the Burke Museum to a local facility where the CT scanning will be carried out. CT imaging will follow the protocol used by the University of Tennessee for scanning their large forensic anatomical collection. The bones are carefully positioned in a double layer box with foam cushions that will be brought or mailed to the Burke Museum. Separated skeletal elements are separated, supported and cushioned by foam supports and dividers that allow multiple elements to be scanned simultaneously without causing direct contact between elements.

Purpose: Cross-sectional properties of long bones have been employed to infer activities and morphological function. The basic information available is the amount of cortical bone and the directions of maximum and minimum bending strength of long bone shafts. In the femur and tibia, these properties reflect activity and mobility. Humerus, radius and ulna properties reflect arm use, and asymmetry can reflect preferential arm use related to certain activities, such as use of an atlatl.

Precedents: Wescott (2001) has obtained femur and humerus cross sectional CT scans of a large number of human populations, including recent Native Americans from the Plains, Southwest, and Texas Coast. These sections will be available for comparative purposes. Numerous papers by C. Ruff have been published detailing cross sectional properties of various recent and fossil human groups (e.g. Ruff 1987; 1994; 2000).
References:

Lundy JK. 1988. A Report on the Use of Fully's Anatomical Method to Estimate Stature in Military Skeletal Remains. *Journal of Forensic Sciences* 33:534-539.

Ruff C. 1987. Sexual dimorphism in human lower limb bone structure: relationship to subsistence strategy and sexual division of labor. *Journal of Human Evolution* 16:391-416.

Ruff C. 1994. Biomechanical analysis of Northern and Southern Plains femora: Behavioral implications. In: Owsley DW, Jantz RL, editors. *Skeletal Biology in the Great Plains: Migration, Warfare, Health and Subsistence*. Washington, DC: Smithsonian Institution Press. p 235-245.

Ruff CB. 2000. Biomechanical analyses of archaeological human skeletons. In: Katzenberg MA, Saunders SR, editors. *Biological Anthropology of the Human Skeleton*. New York: Wiley-Liss, Inc. p 71-102.

Sam Stout, Professor, Ohio State University

Age Determination by Histological Analysis of a Rib Fragment

Purpose: Stout will undertake a histological analysis of a bone sample from the Kennewick skeletal remains. The purpose of the analysis is to provide an independent estimation of the age at death for this individual. The previous assessment of age may be inaccurate.

The analysis requires obtaining a small sample of a rib from the skeleton. A fragment less than two centimeters in length that includes the complete cross-section of the bone is required. Ideally the sample should be from the 6^{th} rib, but any rib other than the first and 11^{th} and 12^{th} would do. More important than rib number is that the sample is taken from the middle third of the shaft. Owsley will select, describe and measure the specimen to insure best selection with minimal effect on the skeleton. The fragment will be photographically documented by C. Clark.

Equipment and Methods: The rib sample will be vacuum embedded at Ohio State University in a plastic resin to maintain its integrity during processing to make thin sections for histological analysis. Several transverse wafers with parallel surfaces and approximately 1-2 mm in thickness are removed using a Buehler Isomet Petrographic saw. The sections are then ground to a final thickness of approximately 80-100 micrometers, and mounted and cover slipped for histological analysis.

Variables: The histological analysis involves determining the following histomorphometric (quantitative histomorphological) variables:

1. Intact Osteon Density (N.On) in $\#/mm^2$, the total number of osteons per unit area (Sa.Ar) that have their Haversian canal perimeters intact or unremodeled. Half or more of an osteon's area must fall within the Merz grid to be counted.

The entire cross section of two rib fields are read in a checkerboard pattern and the results for the two sections averaged.

2. Fragmentary Osteon Density (N.On.Fg) in $\#/mm^2$, the total number of osteons per unit area (Sa.Ar) that lack a Haversian canal or for which the perimeters of their Haversian canals, if present, have been remodeled by subsequent generations of osteons. Half or more of the fragmentary osteon must fall within the Merz grid to be counted. [Figure 1 illustrates the sampling technique for both intact and fragmentary osteon densities.]

3. Mean Osteonal Cross-sectional Area (On.Ar) in mm^2, the average area of bone contained within the cement lines of structurally complete osteons for each rib specimen. Osteons are considered to be structurally complete if their reversal lines are intact. Complete osteons with Haversian canals that deviate significantly from circular structures

are excluded. Mean area is calculated as the average cross-sectional area of a minimum of 25 complete osteons per cross-section.

4. Osteon Population Density (OPD) in $\#/mm^2$, the sum of N.On and N.On.Fg.

$$OPD = N.On + N.On.Fg$$

5. Total Subperiosteal Area (Tt.Ar), total cross-sectional area or the area under the subperiosteum including the marrow cavity, or endosteal area.

6. Cortical Area (Ct.Ar), the amount of cortical bone in a cross-section of bone excluding the endosteal area.

7. Endosteal Area (Es.Ar), the area of the marrow cavity obtained by subtracting cortical area from total area.

$$Es.Ar = Tt.Ar - Ct.Ar$$

8. Relative Cortical Area (Ct.Ar/Tt.Ar), the relative amount of cortical bone in cross-sectional area of bone, or the ratio of cortical bone area (Ct.Ar) to total area (Tt.Ar) of a rib cross-section.

Total subperiosteal area and cortical area are directly computed by scanning the rib thin section on a flatbed scanner and using Image analysis software. Endosteal area (Es.Ar) and relative cortical area (Ct.Ar/Tt.Ar) are derived from cortical area and total area measurements.

Age Estimation: Age at death will be estimated using two histomophometric age estimation methods developed for the human rib: the original method of Stout and Paine (1992),

$$L_n Age = 2.343 + 0.050877 \text{ x } OPD_{rib}$$

and the more recent method developed by Cho et al. (2002).

$$Age = 29.524 + 1.560(OPD_{rib}) + 4.786(Ct.Ar/Tt.Ar) - 5.92.899(On.Ar)$$

In addition to the age estimate resulting from the above two formulas, relative cortical area, cortical area, and osteon area for Kennewick will be compared with data on age associated values for these variables available for modern and several North American archaeological skeletal samples ranging in antiquity from ~7000 years ago to the Mississippian period, and representing a number of subsistence strategies and cultures. The final age estimate will be based upon a combination of the results from histomorphometric formulas and relative cortical area measurements similar to the way Stout approached the age estimate for the Mayan ruler Hanab-Pakal from the site of Palenque (Stout and Streeter in press).

References:

Cho, H., Stout, S.D., Streeter, J; and Madsen, R.W. (2002) Population-Specific Histological Age-Estimating Method: A model for known African-American and European-American Skeletal Remains. *Journal of Forensic Sciences* 47(1):12-18.

Stout SD, and Paine RR (1992) Histological age estimation using the rib and clavicle. *American Journal of Physical Anthropology* 87:111-115.

Stout, SD and Streeter, M (in press) Histomorphometric Analysis of the Cortical Bone of the Rib of Hanab-Pakal. Tiesler, V and Cucina, A (eds): *Studying Janaab'Pakal and Recreating Maya Dynastic History*. University of Arizona Press.

Mark Teaford, Professor, Johns Hopkins University

Purpose: Fifty years ago, investigators realized they could gain insights into jaw movement and tooth-use through light-microscope analyses of wear patterns on teeth. Since then, numerous analyses of modern and fossil material have yielded insights into the evolution of tooth use and diet in a wide variety of animals. The main strength of these analyses is that the microscopic wear patterns are direct evidence of behavior on teeth. As a result, this work can yield unique perspectives on behavioral differences within and between human populations where dental material is available.

Analyses have now proceeded from light microscopy into scanning electron microscopy and confocal microscopy; all based on high resolution epoxy copies of teeth. The goal of the present study is to make high resolution copies of the teeth of the Kennewick material so that state-of-the-art analyses can tell us how those teeth were used, both in terms of diet and various forms of dental parafunction.

Procedure: Techniques will use standard, high resolution dental impression material, specifically, Coltene-Whaledent's "President Jet Regular" polyvinylsiloxane. This material is routinely used on dental patients, with stellar results and no adverse effects, and it has been successfully used on thousands of museum specimens, including the rarest ancient human remains from Africa and Europe, such as nonfossilized Neandertal dentitions. It combines flexibility with dimensional stability and high resolution. Unlike some older materials, it does not require the use of dental trays, and it can be applied specifically to those dental surfaces that one wishes to study. In the case of the Kennewick skeleton, the impression material will be applied only to the chewing surfaces of the teeth. Consequently, even if some of the bone adjacent to some teeth is in poor condition, it will not be affected by Teaford's work since he will not be taking impressions that far down the dental surfaces.

Before the impressions are taken, each tooth will be examined under a light microscope to determine if it has been weakened by cracks or other types of deterioration. If there is any reason to believe that a tooth might be damaged, it will not be copied. Teaford's policy has always been to err on the side of caution and avoid anything that might harm a specimen.

Once the tooth is deemed suitable for copying, it will be carefully cleaned using cotton swabs and acetone, to remove dirt, debris, and fingerprints. As the acetone evaporates quickly, teeth can be cleaned and copied within the same hour. Because the impression material is flexible and dimensionally stable, it separates readily from the teeth and can be removed before stiffening. As a result, it will not separate even loose teeth from the adjacent bone or weaken the connection between tooth and bone.

The dental impressions will be taken back to Baltimore for casting in Teaford's lab. Due to the dimensional stability of the material, the time between impression-taking and casting will be of no consequence to the results of the study. Once the casts have been made, they will be used in scanning electron microscope analyses at Johns Hopkins University. Analyses will involve standard measurements of the microscopic features on tooth surfaces, which can then be compared with those already completed on large samples of historic and prehistoric Native American populations. While the SEM work is being done, the impressions will be sent to the University of Arkansas for the preparation of additional casts for confocal microscopy and scale-sensitive fractal analyses. These analyses will allow the rapid characterization of microscopic wear surfaces in 3D, allowing us to detect patterns indiscernible by standard SEM analyses. The combination of the two types of analyses will allow us to compare wear patterns on all teeth in the Kennewick specimen.

As the confocal analyses are still relatively new (initial descriptions appeared in the journal *Nature* this past August), comparisons of results between techniques will provide an innovative check of techniques. Based on previous SEM analyses of historic and prehistoric Native American remains, we suspect that the Kennewick material will exhibit more microwear than that on historic populations, due to improvements in food preparation techniques in the latter populations. However, if the Kennewick Man consumed large amounts of meat or seafood, he might actually exhibit *less* microwear on his teeth. Only analyses will tell. Similarly, if Kennewick Man was routinely consuming tough foods, we might expect more homogeneously-oriented microwear on his molars, reflecting relatively precise chewing patterns. Wear patterns on his anterior teeth will depend on how he used those teeth in ingesting food and in other activities. If he used those teeth for repetitive, homogenous tasks (e.g., pulling tough materials across the teeth), we might expect homogeneously-oriented microwear. If he used those teeth for a variety of tasks, then we might expect more heterogeneous patterns. Obviously, given the age of the Kennewick material, this represents a unique opportunity for the study of tooth use and microscopic wear, because such analyses have never been attempted on New World material this old.

Bart Cannon, Chief Analyst, Cannon Microprobe

On the 16th of February, Mr. Cannon will briefly examine the embedded projectile point to determine whether it has suitable geometry for analysis. If it looks good, on the morning of the 17th, the following tests will be conducted at Cannon Microprobe, 1041 NE 100th Street, Seattle, located ten minutes north of the campus of the University of Washington.

Procedure A: Energy dispersive electron induced x-ray microanalysis of the projectile point by use of an ARL SEMQ electron microprobe.

It is hoped that a bulk analysis as well as analyses for individual mineralogical phases can be provided. The x-ray spectra can be converted to oxide weight per cent analyses of major and trace constituents of the rock as a whole and of the individual mineral phases.

The electron beam penetrates about 2 microns into the target area and generates the x-ray spectrum from a small volume when in point mode and from a broader area when rastered over a larger area. Some leaching of constituents may have occurred during the last 9,000 years resulting in an analysis that may not perfectly reflect the fresh underlying rock.

In addition to the x-ray spectra, it should be possible to acquire back scattered electron (BSE) scanning electron microscope images of the analysis area. BSE images use the atomic number of phases in the subject to produce the video imaging contrast. Surface topography is also displayed. The images will furnish additional data for the characterization of the projectile. The BSE imaging will assist in the selection of specific analysis sites.

Cannon will first place the specimen directly into the sample chamber with no sample treatment. The circuit path would be enhanced by means of a lightly spring loaded beryllium copper contact placed near the analysis area and continuous on the opposite end with the instrument ground. The electro-static charge from the high voltage electron beam would be further drained by leaking a small volume of argon gas into the sample chamber near the analysis area.

If the above approach fails to disperse the electro-static charge, the sample would be removed from the instrument and masked with aluminum foil. A 3 to 4 mm window would be made to fit over the analysis area. The sample would then be placed in a vacuum chamber and a 40 angstrom film of carbon would be evaporated onto the sample surface through the mask window. The resulting patch of carbon would be nearly invisible and tied to the instrument ground with a "dot" of colloidal carbon paint and a fine copper wire. The carbon film could be removed with a plasma asher or an ultra sonic bath.

Procedure B: X-ray Fluorescence

If the sample geometry is not optimum, it should be analyzed with an x-ray fluorescence instrument. These instruments use X-rays as the excitation and can be operated in air. They do not need any sample coating or other preparations.

Cannon has such an instrument in his inventory, and it is currently being repaired. Efforts will be made to have it operational. Failing that option, a suitable alternative instrument that is either on campus, or portable and capable of being taken into the Burke Museum will be used for this analysis. Most modern art museums now have such instruments since they can be used to characterize pigments on paintings with no harmful effects. Backup instrumentation is currently being investigated.

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