ARCHEOLOGY & ETHNOGRAPHY
PROGRAM

Peoples & Cultures
Recording Our Heritage

Kennewick Man Chapter 2

Report on the Osteological Assessment of the "Kennewick Man" Skeleton (CENWW.97.Kennewick)

Joseph F. Powell and Jerome C. Rose

Index

Introduction

On 25 February, 1999, Joseph Powell and Jerome Rose checked the *Standards* (Buikstra and Ubelaker 1994) inventory prepared by Douglas Owsley for accuracy. Several changes were made, including altering the completeness scores for some bones, moving several bones from one side of the body to another, changing the numbers (L2 vs. L4) of two lumbar vertebrae, and removing one fragment of maxilla from the faunal collection from the site. The corrected *Standards* inventory is attached. These changes were also made on the collections inventory maintained by the Collections Office of the U.S. Army Corps of Engineers. On the following days (26 February - 1 March, 1999) observations and noninvasive data collection were undertaken following the recommendations provided in *Standards for Data Collection from Human Skeletal Remains* edited by Buikstra and Ubelaker (1994). Data collection tasks were divided between Powell and Rose, but all observations of age, sex, and pathology were checked by the other and the final determinations were made after discussion.

In the afternoon of 26 February, 1999, 31 bone fragments were transported under security to the Radiology Department of the University of Washington Medical School (see transportation list). Radiographs were obtained using standard clinical cassettes, film and procedures. A centimeter scale and step wedge were included in all radiographs. Good radiographs of the fine detail were not possible due to the impregnation of all bone by fine grained silt and mineral deposits. Even the spaces in the trabecular bone were filled with mineral deposits. This situation resulted in the bone being almost as radiodense as the stone point embedded in the pelvis. CAT scans were also made of the point in the right pelvis, calvarium, maxilla, left proximal femur, and left distal tibia. Dr. Paul Parsons, Radiology Department, University of Washington Medical School, used the CAT scan data to produce a three dimensional computer model of the ilium fragment and point. Although the point and surrounding bone had almost the same radiographic appearance it was eventually possible to differentiate the bone, remove it from the digital image, and produce a three dimensional model of the embedded point.

On the morning of February 28th, both Dr. Odegaard and Dr. Cassman were present to assess the condition of the fragmented facial bones and to determine the appropriate method of reconstructing these pieces. Once the pieces were refit in correct anatomical position, metric data collection by Powell was completed. The finished reconstruction was then oriented in the Frankfurt horizontal plane and photographed with 35mm color print film using three-dimensional scales in each photograph. Once data collection was completed at the Burke Museum, the reconstructed cranium was transported under security to the Radiology Department of the University of Washington Medical School (see transportation list). On arrival the cranium was inspected for possible movement of refit pieces. Once Powell and Odegaard were satisfied that no movement of the reconstruction had occurred, the cranium was inverted on a soft support, and the skull positioned in the Frankfurt horizontal plane. One millimeter coronal "slices" were then performed via computed tomography (CT), and the resulting slices were reassembled into a three-dimensional computerized model. The production of the CT model and availability of the three-dimensional data will allow other researchers to collect "virtual" measurements from the CT data, and should provide necessary data to create a polymer model of the skull using stereo lithography. The cranium was transported back to the Burke Museum and again inspected for possible movement of reconstructed elements. A second set of craniometric data were recorded from the reconstruction to provide quantitative data on any shifting that may have occurred during transport.

All skeletal data collection was completed on March 1, 1999. Unfortunately, during the recordation of the final two craniometric dimensions in the Gill (1986) system, the several reconstructed pieces of the cranium became partially disassociated. Odegaard and Powell again reconstructed the cranium, and Powell collected a third set of measurements on the skull using the 21 dimensions that might have been affected by the new reconstruction. Comparison of the first and second measurements sets indicated that only one dimension, ectoconchion radius (EKR), was significantly altered by the new reconstruction. There was no more than a 0.38 mm difference for all other craniofacial dimensions. Once all data collection was completed, the individual fragments of the skull were disassociated, the wax bonds removed, and all pieces returned to their storage containers.

Skeletal Reconstruction Methods

Because many of the cranial and postcranial elements were fragmentary and covered with calcium carbonate deposits, it was necessary to refit some broken pieces in order to collect needed metric data from these elements. Given the conservators' concerns regarding the use of permanent adhesives and consolidants, we elected to refit postcranial elements and maintain the stability of fragments by hand. To this end, Ms. Rhonda Lueck, U.S. Army Corps of Engineers, assisted Powell by holding long bone fragment together while Powell recorded the necessary measurements. Measurements were collected only from points that were not obscured by calcium carbonate deposits.

This procedure could not be followed for the measurements of the cranium, since the anatomically correct three-dimensional positioning of fragments is crucial for dimensional accuracy. To solve this problem, conservators Odegaard and Cassman elected to avoid materials that might be permanent, and instead devised an ingenious method for firmly joining craniofacial bone fragments, needed for accurate measurements, while being temporary and nondamaging to individual bone fragments. Cranial pieces were refit using a conservationally stable wax material applied across joint surfaces and to the exposed internal sinus areas in the maxillae. No wax was used between joints, and all fragments fit snugly and in their proper anatomical alignment.

Prior to reconstruction of the cranium, all individual pieces of maxilla, mandible, zygomatics, and the neurocranium were measured by Powell (see Methods below). Facial bone fragments were refit by Powell and Odegaard, with input and assessment by Rose throughout the day-long process. Several times during the reconstruction process, pieces were removed, refit, and reattached to provide the best possible alignment of fragments The anatomical accuracy of the reconstruction was checked at each stage by Powell, and the completed reconstruction was examined by Rose. Only one minor (<1 mm) gap between pieces was present on a break separating the right maxillary and zygomatic bones. This gap was unavoidable due to a slight misalignment of the frontal process of the zygomatic, which had been permanently glued to the body of the zygomatic. This gap did not interfere with metric data collection from the cranium.

Materials and Methods

The inventory and analysis followed the *Standards for Data Collection from Human Skeletal Remains* edited by Buikstra and Ubelaker (1994). Additional cranial, postcranial, and dental data were collected following methods outlined in Brace and Hunt (1990), Turner and coworkers (1991), Holliday (1997), Gill and Rhine (1990), Bass (1989), Martin and Saller (1957), and Powell (1995). These additional data permitted an assessment, based on the physical characteristics of the skeleton and teeth, of the biological affinity of the Kennewick remains. All measurement, scaling system, and trait descriptions were read by observers prior to each data collection session.

Raw comparative data for prehistoric and modern populations were obtained from Howells (1989) and from data generously provided by Dr. T. Hanihara, Tohoku University, Japan. These comparative samples represent world-wide Holocene craniometric variation for 330 populations (N = 8,833). These two databases use slightly different measuring systems; as a result, only those dimensions common to both were used for the analysis of the Hanihara data. Finally, craniometric data for 13 North American Archaic populations (N = 304), dated from 8,000 yr B.P. to 1,900 yr B.P., were used in conjunction with a subset of the Howells and Hanihara modern world data. Comparative data for the Gill (1986) and Brace and Hunt (1990) measurement systems were unavailable. Only male data were used for comparisons presented here. Raw odontometric data for 14 samples (N=869) representing prehistoric and modern world-wide dental variation were obtained from Wolpoff (1971) and from Powell (1995). Postcranial data for modern humans in Asia, Africa, Europe, and the Americas were generously provided by Dr. Trenton Holliday, Tulane University (Holliday 1997). Discrete dental and cranial comparative data were compiled from Turner (1985, 1990) and from summary data compiled in Hauser and deStefano (1989) and Ossenberg (1994).

Osteometric and odontometric data were collected using a variety of calipers, including standard sliding and spreading calipers (GPM), a coordinate caliper (GPM), a simometer (modified by G. Gill), and Mitutotyo digital calipers (with both blunt and pointed tips). Long bone lengths were recorded using an osteometric board constructed of 1mm graph paper (checked for dimensional accuracy of the grid) and free-moving uprights, as well as with a large pair of digital calipers. Prior to each metric data recording session, all calipers were checked for accuracy using a GPM calibration rod scaled from 10mm to 150mm. Dental discrete traits were scored following Turner et al. (1991), using both the ASU Dental Anthropology System plaque and written descriptions for comparison. Cranial discrete traits were scored using descriptions in Buikstra and Ubelaker (1994), as well as illustrations in Hauser and deStefano (1989).

Prior to arriving at the Burke, Powell collected the same battery of craniometric data on a series of six crania in the Maxwell Museum's Documented Collection. Measurements were repeated on these same crania after a period of four days. Additionally, Dr. James C. Chatters generously allowed Powell and University of

New Mexico graduate student Erik G. Ozolins to examine and measure a secondary cast of Dr. Chatter's reconstruction of the Kennewick skull. These data provided a useful comparison for measurements taken on the original specimen, as well as a check on interobserver error. Finally, 21 measurements were repeated on the original Kennewick specimen to determine the differences between the February 28 and March 1 reconstructions.

Rates of intra- and interobserver error are presented in Table 1. Intraobserver error was relatively low, with a mean difference of 0.38mm between sessions. The effects of the two separate reconstructions of the Kennewick cranium were also minimal. The only significant difference in measurements noted was between the Chatters cast and the Powell reconstruction of the original (Table 1). Some of these differences are attributable to differences in measurement technique between Powell and Ozolins, and differences in the ability to accurately determine certain landmarks on the cast. The considerable suture obliteration on the original specimen made it particularly difficult to visually determine bregma, though it was possible to locate this point through palpation of the coronal and sagittal sutures in the original. Bregma could not be accurately located on the secondary cast.

The comparative craniometric data were tested for univariate and multivariate normality, and outliers were trimmed using a SAS macrolanguage program. Other variables exhibiting univariate nonnormality after trimming were excluded from further consideration, leaving 52 Howells variables and an additional 28 dimensions from the Brace and Hunt (1990), Bass (1989), and Gill (1986) measurement sets (Table 2 and Appendix I). From these 52 basic dimensions, others were deleted due to intra- or inter-observer error greater than 1.1 mm. Four main variable sets were derived from the full Howells variables, including:

1. the 52 primary dimensions (after removal of nonnormal data and variables that could not be observed in Kennewick)
2. a set of 49 variables with low intraobserver error
3. forty-five variables exhibiting low intra- and interobserver error
4. thirty-three dimensions that had low error and that could be obtained without reconstruction of the cranium (Table 2).

Although all variable sets produced generally similar multivariate results, only the analyses of the 52, 45, and 33 variable data sets are presented below.

After deleting all female observations and those with missing values, the craniometric and odontometric data were adjusted for size differences following Darroch and Mossiman (1985). Thirty-one of the 34 Howells populations were used in craniometric analyses; the Anyang, Egypt, and Andaman groups were eliminated because their covariance structures were not typical of other Howells samples. Size-corrected data were employed in principal components analysis, canonical variates analysis, and discriminant function analyses.

Principal components analysis uses the pooled covariance structure of all samples to reduced the original data to a series of "principal components" of variation that best describe the original samples. Individual PCA scores were generated, and the centroid for each group plotted using three-dimensional ordination. Canonical variates analysis follows the same approach, but uses a pooled within-group covariance matrix for determining relationships among groups. This has the effect of reducing within-group variation and increasing between-group variation-- making samples as distinctive as possible. Kennewick was allocated to groups using a posterior probability derived from a discriminant function analysis. The posterior probability represents probability that an individual falls into one of the reference populations used in the analysis, which may be unrealistic for ancient human remains. Finally, Mahalanobis generalized distance, D^2, was used to construct a typicality probability following Albrecht (1992) and Van Vark and Schaafsma (1992). The typicality probability is useful when the unknown individual may not belong to any of the reference groups, and indicates the relationship between the unknown individual relative to the variation present among the reference samples.

Following Van Vark and Schaafsma (1992), the principal component scores were also used to generate inter-individuals distances as a means of determining to which populations in the PCA ordination the Kennewick remains were most proximate in multivariate space. Only the principal components with eigenvalues greater than one were used in this assessment (Van Vark and Schaafsma 1991). This method provides an assessment of inter-individual distances, but reduces overall variation between groups, making it more likely for the Kennewick skeleton to be included as a "neighbor" to other populations than the original data or the raw size-corrected dimensions. Typicality probabilities generated from these principal component scores are extremely unconservative-- thus the typicality probabilities are exaggerated and should be viewed with caution. This less conservative approach was used to provide the "best case" scenario for group proximity, assuming that the Kennewick remains may not have been drawn from the variation observed in the reference samples. Low typicality probabilities for a population derived under this method suggests that the population in question is morphometrically unrelated to the Kennewick skeleton.

Results

Age and Sex

All morphological traits of the skull and pelvis scored in the male category. With the exception of the midlambdoid and anterior median palatine sutures, all others listed in the *Standards* volume (Buikstra and Ubelaker, 1994) were closed. The internal aspects of the sutures could not be viewed because the calvarium was filled with matrix. The sutures suggest an old age-at-death. The pubic symphysis and auricular surface morphology suggest an age of 45-50 years.

Dental Anthropology

The teeth are all present except the right maxillary third and left mandibular third molars. The incisors, canines, and premolars are extensively worn with wear scores mostly between 7 and 8 using the Smith wear system. All show wear angled to the lingual side of the tooth. The maxillary first molars have no enamel (score of 40 on the Scott system), while the mandibular molars have some enamel with left and right scores of 32 and 36 respectively. The second molars score between 30 and 37 and the remaining third molars score 17. This wear gradient from the first to third molars indicates very extensive and rapid tooth wear (i.e., considerable enamel removed per year). All the exterior/occlusal surfaces of the pulp chambers are filled with secondary dentin and none are exposed. The CAT scans show that only the maxillary canines have any of the pulp chamber not filled with either dentin or perhaps natural minerals from the burial environment. These two teeth may offer the best source for uncontaminated DNA. Radiographs show a similar infilling of the mandibular teeth with secondary dentin and possibly some environmental minerals. The left mandibular first molar, left premolars, right second molar and the premolars have some empty pulp chamber left. Again, these teeth might be excellent sources of DNA. The teeth all demonstrate an excellent secondary dentin response to the extensive tooth wear protecting the living pulp chamber from the environment. Thus, the amount of tooth wear did not exceed the teeth's capacity to cope. There are no caries or pulp inflammation. There does not appear to be any calculus build up on the teeth, although they have been cleaned and calculus deposits could have been removed. However, it is certain that if there were calculus that it was neither wide spread nor extensive. The left maxillary third molar shows a small trace of calculus deposit.

With only traces of enamel remaining on any of the teeth it is not possible to reconstruct a childhood stress profile from the distribution of enamel hypoplasias. The maxillary second left molar has one small linear hypoplasia located 2.26mm from the cemento-enamel junction. This suggests a childhood stress episode at 6.0 to 6.5 years of age. The mandibular right canine shows a small hypoplasia at 1.66mm from the cemento-enamel junction indicating stress at 5.0 to 5.5 years of age.

Dental discrete traits were difficult to observe given the considerable attrition of the dentition. Dental discrete traits in Kennewick include no UI1 interruption grooves, single-rooted UP3s, no UP3 distosagittal ridge, 3-root LM1s, strong enamel extensions on upper and lower molars, no peg or absent UM3s, no Tome's root, and two-rooted LM1s. Although it is tempting to try to assign Kennewick to either the Sinodont or Sundadont (Turner 1990) patterns, it is simply not possible to attribute the Kennewick individual's dental discrete traits to either the Sinodont or Sundadont groups based on gross morphological observations. The east Asian Sinodont and Sundadont dental patterns are based on the relative *frequencies* of eight key traits observed in large samples of Asian populations. Any one individual drawn at random from a Sinodont or Sundadont group might exhibit all, some, or none of the characteristics associated with that group's overall pattern of frequencies. However, more complex statistical methods, assuming that Kennewick Man's dental data are representative of the population from which he was drawn, can be used to assign a probability of group membership in reference populations (see Discrete Data Analyses below).

Paleopathology and Taphonomy

On the left portion of the frontal above the eye there is a small 6.6 x 6.0mm depression. There is no irregularity of the bone surrounding the depression. Matrix inside the calvarium makes it impossible to see the internal table. This depression cannot be seen in any of the radiographs or CAT scans. It does not appear to penetrate the internal table. No importance can be attached to this small depression and it does not appear to be anything significant, such as a fatal wound. It most likely represents a minor trauma. The nasal bones are prominent and projecting and there is a slight deviation to the left. Examination of the bone, radiographs (some taken just for examination of the nasals), and the CAT scans reveals no anomaly and there is no evidence for a healed fracture. The mandible, maxilla and other facial bones do not exhibit any pathological lesions.

The right clavicle has a small reaction area with a maximum width of 11.0mm on the medial end just lateral to the articular surface. The interior surfaces of the lesion are smooth. Dirt prevents a detailed examination of the interior surfaces that might have located resorption lacunae. The lesion is clearly seen on the radiograph, but there is no sign of spreading infection. The insertion point of the sternohyoid muscle is just lateral to the reaction area and it is possible that this resorptive reaction area is associated with this muscle. It is even possible that the sternocleidomastoid or pectoralis muscles could be involved. A bacterial infection does not appear to be involved and, thus, these lesions might be associated with a torn ligament or inflammation associated with muscle use. The left clavicle has a similar, but smaller (width of 7.1mm), lesion in the same location. The bilateral nature of these lesions argues against infection and for an association with muscle use.

Both scapulae are fragmented, but the glenoid cavities, acromion processes, and spines are preserved. No anomaly is present.

The right humerus has rodent gnaw marks on the proximal midshaft quarter that are old, stained, and filled with matrix (Table 3). The size of the marks suggest a medium sized animal. The rodent gnawing took place when the skeleton was interred within its original location. Such rodent gnawing is common on skeletons found in their original burial location. There is one new cut scar on the proximal shaft quarter. The bone shows green algae stains on the distal shaft and end. The algae stain is the product of recent exposure within a damp/wet environment and occurred after the grave was disturbed and prior to discovery of the skeleton. Such staining is common on forensic cases where the body/skeleton has been exposed to the environment and becomes covered with water in a puddle or other body of water. The muscle markings are clear and well developed. The midshaft is bowed medially and suggests hyper development from extensive usage. The radiographs clearly show the build up of cortex along the lateral surface of the shaft especially within the region of the deltoid muscle insertion. This shape is not uncommon on individuals who engage in rigorous use of the arm such as modern weight lifters or construction laborers. The angle of the distal half of the shaft with the proximal half is at or just past the extreme end of the normal range. This angle in conjunction with the cortical expansion seen on the radiograph indicates a well healed fracture from early life. It is most likely to have been prior to adulthood and probably when the individual was between 15 and 20 years of age. There is no degenerative change on any of the joint surfaces.

The distal half of the left humerus is stained with algae. Muscle markings are also extensive and the shaft is hyper-developed. There are no degenerative changes on any of the joint surfaces. The olecranon fossa is perforated and the surface exhibits a resorptive reaction area. This reaction is not due to bacterial infection or the joint surface would have been impacted. The reaction, and the associated perforation, are most likely due to inflammation resulting from frequent hyperextension of the forearm while engaged in some habitual activity. This would certainly explain the hyper-development of the shaft and well-developed muscle markings. As with the right humerus, the left humerus shows extensive development of the shaft in the area of the deltoid muscle, but the bending of the shaft is not as extreme as it was with the right humerus. Again extensive muscle use is postulated to explain the morphology of the left humerus. Extensive muscle use is also evident in the highly developed interosseous crests of the radii and ulnae which corroborates this interpretation.

The right radius displays an algae stain on the distal segment and well developed radial tuberosity. The left radius has a similarly well developed radial tuberosity and does not show staining or rodent gnawing.

The right ulna shows algae stains on both proximal and distal end and rodent gnawing at the proximal end of the shaft. The tooth marks here are small and suggest a small animal. There is no staining or soil in the gnaw marks and it is possible that these occurred during the surface exposure just prior to discovery. There is some minor lipping of the joint margin, but the articular surface is smooth. The left radius also shows algae stains on the proximal end. There is slight lipping of the joint margin, but no deterioration of the joint surface. There is a minor resorptive reaction area on the margin of the olecranon process which corresponds to the reaction area of the humerus. However, it is not possible to be sure that this is not postmortem erosion. However, the similarity of the reactions on both humerus and ulna of the left elbow suggest that they are related. Both ulnae exhibit well developed muscle markings.

The 2nd, 3rd and 4th right metacarpals and a first row third phalanx of the right hand have algae staining. The 4th metacarpal of the right hand has 9 small rodent gnaw marks. The superior surface of the distal end of the first row third phalanx exhibits pitting just below the articular surface, but this is clearly postmortem erosion. The left hand exhibits no abnormality except that a third metacarpal exhibits a red patchy stain (97.L.16.MCa).

Many of the numerous rib fragments had been fitted together and many more, especially on the right side, were fitted during the examination by Rhonda Lueck. One unidentified right rib fragment (97.I.12d .11) had rodent gnawing along 15.69mm of its inferior border and also exhibited red staining. Fragment 97.I.12d.5 also has a red stain. Unidentified right rib fragment 97.I.12a.1 has one end pinched closed with no loss of superior-inferior width. The cortex continues from the rib to the edge of the pinched end without any disruption on the surface or signs of rarefaction. There is a small smooth walled lytic lesion at the superior corner of the pinched end of the rib. This is probably some sort of cyst with no signs of inflammation or remodeling. The radiograph also shows no disruption of structure anywhere within the fragment. Whatever the cause of this break, it had happened many years before death. Another unidentified fragment (97.I.12a.7) also has a pinched off end similar to the one just described. The other end of this fragment is a normal medial rib end. There is some postmortem damage on the pinched end. Again there does not appear to be any surface or internal (viewing the radiograph) disruption of structure, but simply a gradual narrowing of the bone thickness. Placing these two fragments end to end suggests that they are two parts of the same rib fitting pinched end to pinched end. These two fragments could be either right rib 7 plus or minus one number. This suggests that they represent two portions of a pseudoarthrosis or false joint resulting from a fracture that could not heal because the two broken portions could not be stabilized due to movement during breathing. The trauma causing this break would have occurred many years prior to death. It is most likely that this trauma occurred at the same time as the fracture of the right humerus.

Unidentified right rib fragment 97.I.12a.9 also has a pinched end although the smooth edge is slightly abraded probably after exposure of the burial. Similar to 97.I.12a.1, described above, there is a small smooth walled lytic lesion on the superior surface just before the pinched off end. Similarly there is no disruption of the surface or interior structure of this fragment. Again this resembles a long healed pseudoarthrosis. Fragment 97.I.12a.3 is very small and was originally identified as a left rib fragment. It is also pinched off and what looks like a reaction area (possible infection) is mechanical postmortem damage exposing the trabecular bone. The most parsimonious interpretation is that this small fragment is the other side of the pseudoarthrosis from 97.I.12a.1 and that this is actually a right rib fragment. These two fragments could have come from right rib number 6.

Among the left ribs there are 27 fragments that have what looks like red staining. Two fragments exhibit algae stains. Left third rib fragment 97.I.12a.2 has an 8.6mm wide vertically oriented depression of about 1.1mm in depth. This appears to be a commonly seen normal variation. The radiograph shows normal internal structure. It is possible that this is a normally healed fracture from many years before death. Such fractures are common in both modern and ancient skeletons. Fragment 97.I.12a.5 is very similar and the radiograph shows a normal internal structure. Fragment 97.I.12d.4 is from the right tenth rib and has 2 small vertical grooves with algae staining indicating that they are postmortem marks made prior to discovery. Fragment 97A.I.12d has broken edges rounded by mechanical abrasion probably during water transport just prior to discovery.

The atlas, axis, and third cervical vertebrae (97.U.4 C1a - C3a) exhibit algae staining. The axis vertebra has a shortened spinous process (97.U.4C2a), the third vertebrae has a spinous process that appears pinched off (97U.4.C3a), while the fourth vertebrae has a short spinous process (97U.4.C4a). All of these features are within the normal range of variation and are associated with muscle usage. The thoracic vertebrae exhibit algae staining, but no other anomaly.

The second lumbar vertebra (97U.6.L4b) has a small amount of osteophytic lipping along the vertebral body. Lumbar vertebra 4 (97U6.L2b) exhibits minor osteophytic lipping along the superior body margin and along the inferior body margin (97U.6.L2a). The latter has a small perforation along the rim. This osteophytosis is very minimal and of no consequence. There is a red staining of the articular facet of 97U6.L2c.

The right innominate is fractured into six large pieces, but is relatively complete. A stone projectile point or knife is embedded in the ilium, just below the iliac crest about midway along the iliac arc. The point is visible through a medial window through the bone measuring 34.49mm anterior-posteriorly and 10.98mm superior-inferiorly. There is a similar window through the cortical bone on the lateral side measuring 18.06mm anterior-posteriorly and 16.19mm superior-inferiorly. These windows have smooth edges and are the result of natural biological processes. In a few locations the interior surfaces of the bone can be observed due to a space between the bone and the stone point. The bone surface is smooth compact bone. The entrance area of the point is completely healed and there is no scar. Medial-lateral radiographs show normal trabecular pattern around the point indicating complete healing and no sign of infection. The CAT scans clearly show the healed compact bone around the point and normal trabecular structure interior to the compact bone. The open space between the point and the bone is clearly seen on the CAT scan. John Fagan's examination of both radiographs and CAT scans show that the tip of the point is anterior (ventral) and the butt is posterior (dorsal). Overall appearance suggests that an inflammatory barrier (fibrous tissue) was formed around the point as part of the normal healing process. If there was an infection associated with this wound it was minor and healed long before death leaving no evidence. The point would have come from the rear and slightly below horizontal entering the iliac blade through the posterior edge. There would have been no organ damage, minimal muscle damage, and no major blood vessels would have been severed. Considerable force would have been needed for the point to penetrate the bone so deeply. There is no sign of past infection and healing could have been very rapid once the shaft and haft had been removed, most likely breaking off at impact. This wound would have occurred several and more likely many years (most likely decades) prior to death. The sciatic notch of the right side (score of 5) is narrower than that of the left side (score of 4). This asymmetry could be associated with the point which also disrupted the form of the iliac crest. If the notch asymmetry is associated with the point, then the wound would have occurred prior to growth completion of the pelvis. Thus, this person was younger than 20 years of age and more likely closer to 15 years at the time of event. It is most likely that this trauma occurring at a young age is associated in time to the broken ribs and right humerus. There are no other anomalies on the right pelvis.

The left innominate is broken into four segments. The inferior border of the acetabulum has a 10.01mm wide notch that is not found on the right. This notch could be associated with an extreme habitual positioning of the femur, such as in crossing the left leg over the right. No other abnormalities are present.

Only the distal one third of the right femur remains. The lateral condyle has a rough spot on the superior surface indicating initial joint surface deterioration and arthritis. There is no marginal lipping. The anterior articular surface exhibits an algae stain. Only the superior half of the left femur remains and there are no abnormalities.

The right patella has slight lipping of the lateral articular margin, while the left patella has similar lipping of the medial margin. Both are within the range of normal variation. The right tibia is almost complete, but broken into four pieces. The anterior surface is striated, but it is not possible to determine if it indicates an old healed infection or is postmortem damage. The surface is covered with a heavy matrix deposit making it difficult to observe the surface. No significance is attributed to the striations. There is a rough spot on the medial articular surface indicating initial deterioration and arthritis. There is a red ochre-like stain on both the anterior and posterior surface of the shaft. The left tibia is almost complete, but broken into three fragments. The surface is also obscured by heavy matrix deposit. An algae stain is located on the proximal portions. A patch of large gnaw marks are located on the anterior crest on the proximal middle quarter.

Two patches of rodent gnaw marks are found on the right fibula and one on the left. There are no other abnormalities.

The talus of the right foot exhibits algae staining. The calcaneus has slight marginal lipping within the normal range on the medial talar articular surface and the posterior talar articular surface. The anterior talar articular facet is separated from the medial talar articular facet by a deep well developed groove. Although anomalous, no interpretation can be provided. The remaining bones of the foot exhibit no abnormality. The calcaneus and talus of the left foot show no abnormalities. A left 4th metatarsal has gnaw marks at three locations on the shaft. Two phalanges (97.L.24.Pb and 97.L.24.Pa) have a red ochre like staining.

Nine of the unidentified human bone fragments appear to have red staining. Three of the unidentified faunal fragments are algae stained.

Summary of Taphonomy

The virtual completeness and excellent condition of the skeleton, including the small bones of the hands and feet, suggest that the skeleton was deliberately buried in a grave when the body was completely fleshed. The skeleton exhibited no loss of small bones that is characteristic of forensic cases that had been exposed on the surface. The smaller bones are usually carried off by scavengers. The rodent gnawing observed on the skeleton is also characteristic of skeletons that are excavated from graves.

To test the pattern of element recovery and damage against human remains from known taphonomic contexts, we compared the element representation for Kennewick against five patterns observed in a taphonomic database housed at the Maxwell Museum of Anthropology. Forensic cases include those from various recovery contexts in the desert southwest, as well as the large database for Washington state compiled by Haglund et al. (1988, 1989). Five patterns were compared: intentional burials, canid-scavenged remains, bear (*Ursus americanus*) scavenged remains, remains recovered from rivers and lakes, and remains washed ashore on river banks and beaches (Figure 1). Patterns of element recovery in Kennewick were compared using a two-tailed Kolmogorov-Smirnoff test. The pattern observed in the Kennewick remains are clearly distinctive from scavenged remains and those recovered in beach and water environments (Table 4), but could not be distinguished from intentionally buried remains. Although the sternum was missing from the Kennewick remains, this element is typically recovered in 40% of canid scavenged remains and in 80% of remains from rivers and lakes (Figure 1).

The algae stains indicate that after the grave was uncovered by natural processes it spent some time (at least several weeks) immersed in shallow water. The red staining seen on many of the bones is similar to the staining observed on other skeletons where the body had been coated with red ochre-based paint prior to burial. This supposition requires that the chemical composition of the red stain be determined and interpreted within the context of the surrounding matrix to ascertain if the staining is of natural or cultural origin. However, if this is of cultural origin, it is pattern seen in eight (53.3%) early Holocene human burials of the 15 burials for which we have such data. Furthermore, intentional burial appears to have occurred in the vast majority of early Holocene remains from North and South America (Powell, 1999, in press).

Many of the transverse cracks in the bones could have occurred while the skeleton was buried, while most of the longitudinal cracks occurred after exposure and during the drying process. The radiographs show that virtually every bone is filled with matrix. When the bones dried out for the first time, the matrix and bone would shrink at different rates and the bone would be splintered. Many microcracks can be seen in the radiographs and CAT scans indicating that the bone is being held together by the matrix inside the bones.

Stature

The estimation of stature relies on the premise that the individual for whom an estimate is generated was drawn from one of the reference populations used to produce a regression coefficient. This is clearly not the case for the Kennewick remains. However, we elected to use the most complete set of long bones (Appendix II and Tables 5 and 6) to produce an estimate of living stature. The bones of the arm were more complete than those of the leg, and were used in a series of stature formulae specific to those elements. However, stature estimates from the arm are not as accurate as those from lower limb bones. The most accurate bone for estimating stature, the femur, was extremely fragmentary and incomplete due to loss after recovery. Instead we elected to use the more complete tibiae for estimation. Fragmentary tibiae were used to estimate complete bone lengths following Steele (1970). We then used these estimates in standard regression formulae. Standard errors for the double estimation were modified accordingly.

Based on the more complete arm elements, the stature of the Kennewick individual is best approximated by humeral dimensions regressed on modern Mongoloids (Table 5). This produced stature estimates ranging from 173.9 to 177.3 cm (5' 9" inches to 5' 10"). Arm estimates have a standard error of 4.25 to 4.66 cm (1.6" to 1.8"). Stature estimates based on fragmentary elements of the leg are presented in Table 6. Mean stature estimates, across all reference samples (Table 6) provide a range of 172.70 cm to 178.36 cm (5' 8" to 5' 10").

Biological Affinity

Determinations of biological affinity were made using both objective and subjective approaches. In the former case, multivariate analyses were used to generate probabilities of group membership, while in the latter case comparisons were made to known patterns of discrete morphological variation among extant forensic samples in the U.S. Two caveats should be emphasized in the interpretation of the bioaffinity results. First, the Kennewick research team was charged with determining whether the remains were those of a Native American individual; although the federal statute is somewhat ambiguous as to how the term "Native American" is defined, we took this as indicating a modern or recent human population indigenous to the Americas. Based on this goal, we derived the following hypotheses:

H_0: Kennewick represents an individual drawn from a population of recent (late Holocene) Native Americans

H_A: Kennewick does not represent an individual drawn from a population of recent Native Americans.

The method for examining these hypotheses is drawn from logical empiricism, so that any null hypothesis can only be rejected, **but can never be proven to be true**.

It may be possible to exclude Kennewick from membership in the Native American comparative samples used in the following analyses, but it is not possible to prove that Kennewick is, in fact Native American (i.e., prove the null hypothesis to be true). Secondly, the ability to properly allocate prehistoric remains to a particular population or race depends, in large part, on whether the comparative samples are representative of the population from which the unknown person is drawn, and on the assumption that the such reference groups existed in the distant past. The use of typicality probabilities provides a statistical measure of association and group membership that does not assume that the individual examined is drawn from one of the comparative samples. Finally, it is important to recognize that the Kennewick remains may be thousands of years older than any of the reference samples used in these comparisons. Unless morphological "types" extend far into the past, it may be difficult to place the Kennewick remains into any late Holocene sample used for comparison.

Powell has already noted (Powell 1995; Powell and Neves n.d.; Steele and Powell 1992, 1994) that the geographic groupings or races seen among modern peoples are at best fuzzy and at worst non-existent when examining late Pleistocene and early Holocene populations world-wide. This point has also been noted by Kamminga and Wright (1988) in their analysis of the late Pleistocene skeleton from Upper Cave, Zhoukoudien, China. Thus it is possible that the term "Native American," when used in a biological context, is irrelevant when applied to ancient human remains because founder populations did not exhibit the pattern of morphological and metric variation seen among late Holocene populations in the Americas. However, such a situation does not completely rule out the possibility that these ancient remains might be biologically ancestral to modern American Indian populations (see Powell 1997; Powell in press, and Powell and Neves for data supporting this view). Much of the interpretation of the biological affinity of Kennewick results depends on subjective opinions and assumptions about the rate of morphological change possible during the past 10,000 years, the underlying genetics of the traits examined, and the demographic history of early and late Holocene humans in the New World.

Because the bulk of the skeletal reference samples are of late Holocene (modern) age, the comparisons using these reference groups do not allow us to evaluate the biological similarity of the Kennewick remains to ancient populations in the Americas, particularly to other skeletons of early and middle Holocene age. Because of the small number of Paleoindian and Archaic period skeletal series available for comparison, these results are not as definitive. However, they do provide an assessment of overall morphological similarity and dissimilarity between contemporaneous human groups present in the Americas from 9,000 to 5,000 years before present.

If the Kennewick remains represent a member of a founding population whose descendants evolved *in situ* over the past 9,000 years, North and South American populations who appear later in time *may* be dissimilar to the founder population due to the cumulative effects of genetic drift, mutation, and natural selection over time. An alternative explanation is that the Kennewick remains represent an individual with no living descendants among modern American Indians. Human skeletons from the middle and late Archaic periods (8,000 1,900 yr B.P.) represent the temporally adjacent sample for comparison with Kennewick, for testing the following hypotheses:

H_0: Kennewick represents an individual drawn from a population of Archaic (middle Holocene) Native Americans

H_A: Kennewick does not represent an individual drawn from a population of Archaic Native Americans.

This set of hypotheses allowed us to examine the possibility that the remains are unlike modern American Indians, yet similar to temporally adjacent Archaic populations in the New World. To test the null hypothesis, we collected craniometric data for 13 skeletal series dating to the Archaic period (8,000 - 1,900 yr B.P.) in North America. One caveat should be noted: even if there is a strong similarity of between Archaic groups and the Kennewick remains, this does not necessarily provide evidence to support or refute a connection to later American Indian populations. Only a time series analysis of populations from the Plateau region, extending from earliest occupation to the historic period, can provide a statistically valid means of assessing morphometric continuity of populations through time. Data for performing such an analysis are currently unavailable.

Craniometric Analyses:
The first analysis of craniometric data utilized the primary variable set of 52 dimensions (Table 2). In the canonical discriminant analysis of the primary variables, Kennewick falls between modern Amerindians and southeast Asian groups (Figure 2), a pattern noted for other ancient North American remains by Steele and Powell (1992, 1994). When the size-corrected data are used to generate posterior probabilities of group membership, the Kennewick individual has the greatest probability of inclusion in the South Japan sample ($p_{posterior} = 0.9861$), followed by the South Pacific Moriori ($p_{posterior} = 0.0081$) and North American Arikara ($p_{posterior} = 0.0021$) samples. If the chronometric age of the Kennewick remains is correct, it is unlikely that the Kennewick skeleton belongs within any modern population, so that a typicality probability is the better assessment of group membership. Typicality probabilities were all $p_{typicality} < 0.00000001$ for all population comparisons using all combinations of the original size-corrected variables.

The first three principal components from the principal components analysis of all 52 variables account for only 39.22% of the total size-corrected variation in the data. The PCA plot (Figure 3) places the Kennewick individual as an outlier compared to full Howells data (N = 22 populations). Using the principal component scores to generate inter-individual distances (Van Vark and Schaafsma 1991), the Kennewick individual is closest to south Pacific (Moriori, Easter Island) and the Ainu of Japan. The typicality probabilities for the PC reduced data, which are the least conservative estimates of group membership, all indicate that the Kennewick cranium is not morphologically similar to any modern human population (Table 7). No modern Native American group is included as a close neighbor in the least conservative approach, which strongly suggests that they bear no morphological resemblance to the Kennewick remains. Furthermore, while the inclusion of the Ainu as a nearest group could be interpreted as a possible "Caucasoid" morphology for the Kennewick remains if one considers modern Ainu to be "Caucasoids" (see Jantz and Owsley 1997); we view this as a reflection of the southern Asian/south Pacific morphology of the Kennewick skull given that most researchers tend to associate Ainu groups with earlier population originating in southern Asia (Brace and Hunt 1990; Turner 1985, 1990).

While the above results are interesting, they include a number of variables that tend to exhibit a high degree of intra- and inter-observer error (see Table 2). After removing variables that were univariately non-normal in the comparative data, or that exhibited low repeatability or high inter-observer error, the above analyses were repeated using the best variable set. This variable set contained 45 dimensions of the face and neurocranium, including several radii (Table 2), and was compared to over 2,000 males in the Howells (1989) data

The canonical variates analysis places Kennewick closer to southern Asians, and nearly equidistant to modern Native Americans and Polynesians (Figure 4). The discriminant analysis based on the 45 best variables is highest for South Japan ($p_{posterior}$ = 0.9007), followed by Moriori ($p_{posterior}$ = 0.0765), and Ainu ($p_{posterior}$ = 0.03115). Typicality probabilities were all zero for the Howells comparative samples, suggesting again that the Kennewick skeleton morphologically is unlike any modern human population. A plot of the principal component scores places Kennewick in a peripheral position relative to the bulk of Polynesians and southern Asians, as well as to the Ainu sample (Figure 5). The first three components account for 38.54% of the size-corrected craniometric variation in the Howells data set. Based on inter-individual Mahalanobis' distances, the most proximate group to Kennewick was Moriori, which produced one of the largest typicality probabilities observed ($p_{typicality}$ = 0.1338). Other "neighbors" to Kennewick included northern and southern Moriori, Ainu, and the Arikara sample (Table 8).

Because the Howells (1989) data contain only three Native American populations, the potential biological affinity, or lack thereof, between Kennewick and recent American Indians cannot be fully assessed without addition of other American Indian samples. A larger comparative data set for world-wide populations, generously provided by Dr. T. Hanihara (1996), was used to examine the relationship between Kennewick and late Holocene populations in North and South America. This data set, which contains 48 cranial dimensions for 296 populations (N = 6,310 individuals), was used to generate both principal components and discriminant scores for the Kennewick remains.

Because the Hanihara data contain some variables that are defined differently than those in Howells, only dimensions that were defined and measured in the same way as Howells (1989) were used: GOL, XCB, XFB, BNL, ASB, BPL, NLH, NLB, MAB, OBH, FRC, PAC, and OCC. These 13 variables were size-corrected as before, and used to generate principal components, canonical variates, and linear discriminant functions. Due to missing data for many observations, only 183 populations (N = 4,179) were used for comparison, including 19 North and South American populations. Prehistoric groups from the states of Washington and Oregon were included, as were populations from Alaska and British Columbia.

In the canonical variates analysis (Figure 6), the Kennewick skeleton was separated from other modern populations on all three canonical axes, though it fell closest to the south Pacific samples. The four largest posterior probabilities of group membership, using 13 size-corrected variables were: Moriori ($p_{posterior}$ = 0.2757) Papua New Guinea ($p_{posterior}$ = 0.0848), Marquesas ($p_{posterior}$ = 0.0753), and California ($p_{posterior}$ = 0.0657). Mahalanobis distances between Kennewick and other group centroids produced low typicality probabilities (Table 9).

The principal components analysis (Figure 7) shows that Kennewick falls within the range of other modern groups for the first two components, but away from modern populations on the third component. The first three components account for 50.84% of the total craniometric variation present. When Mahalanobis distances were computed from PC scores, the Kennewick individual was closest to the Moriori sample ($p_{posterior}$ = 0.3954), followed by Society Islands ($p_{posterior}$ = 0.0945) and Sakhalin ($p_{posterior}$ = 0.0616). Mahalanobis distances for the PC data are provided in Table 10. The five closest groups included Polynesian and northeast Asian populations, while the five most distant groups included Africans, Europeans, and the prehistoric Tennessee samples. Typicality probabilities for all groups were less than 0.10 (Table 10).

A final point of concern involved the reconstruction of the Kennewick skull used for the above analyses. The differences between the measurements taken on the Kennewick Man cast and the Powell/Odegaard reconstruction were statistically significant, suggesting that some reconstruction differences were present in the data analyzed above. Although the fit of pieces was firm, with no observable gaps, it is possible, if unlikely, that the results obtained above are the result of an artifact of the reconstruction. In order to avoid reconstruction bias, multivariate analyses were performed using only those dimensions that were not affected by the reconstruction of the complete skull. Variables deleted were those involving prosthion, subspinale, zygomaxillare, zygoorbitale, and ectoconchion, as well as those already removed because of potential inter- and intra-observer error. This variable set should be the most conservative and, potentially, most accurate of those generated in the Kennewick Phase I study.

The canonical variates analysis for the 33 variable data set placed clearly within the cluster of Polynesian samples, and far from the three American Indian groups (Figure 8). The discriminant analysis of the 33 size-corrected original variables place Kennewick within the South Japan sample ($p_{posterior}$ = 0.9425), followed by Moriori ($p_{posterior}$ = 0.0173) and Ainu ($p_{posterior}$ = 0.0096) samples. None of the typicality probabilities for the Howells populations were greater than zero.

The first three principal components derived from these data accounted for 41.63% of the total size-corrected variation. The PC plot (Figure 9), places Kennewick near the periphery of modern samples, but closest to two northern Asian populations. The inter-individual distances were smallest for the Ainu, Moriori, South Japan, Zalavar, and Easter Island groups, and largest for Berg, Tolai, Tasmania, Australia, Bushmen samples (Table 11). None of the typicality probabilities were greater than 13%, suggesting that with the less conservative PC data, Kennewick could not be attributed with certainty to any of the modern samples. One additional point to note is that with the non-reconstructed variables, two so-called "Caucasoid" groups-- Ainu and Zalavar-- were indicated as most similar to Kennewick in multivariate space, while none of the American Indian samples were close to the Kennewick skeleton. This is not to say that the Kennewick remains are those of a "Caucasoid" individual. It does, however, confirm the work of other researchers (Steele and Powell 1992, 1994; Jantz and Owsley 1997, in press) which indicate that early New World populations have some features shared by some modern Polynesian and European groups. The cranial nonmetric and dental data confirm the Polynesian morphology of the Kennewick skeleton, but do not suggest a morphological similarity of this individual to modern populations of Europe.

To assess the relationship between the Kennewick skeleton and Archaic North American groups, we selected ten variables common to the Howells, Hanihara, and Archaic data, excluding variables with different landmark definitions, for analysis. The pooled modern samples (N=7,142, 277 groups) were corrected for size and tested for interobserver effects. Mahalanobis distances for these samples were used to generate typicality probabilities for these data; the PCA and canonical plots contained too many individual populations to be of any utility. Results are presented in Table 12. Based on the 277 prehistoric and modern reference samples, the five closest populations included Eskimo, Northeast Asians, and Polynesian groups, while the five furthest samples included the majority of Archaic groups and one Near Eastern sample (Table 12). Typicality probabilities were high, with Kennewick exhibiting a 91% probability of having been drawn from the sample of Chukchi from Siberia. Typicality probabilities for the remaining proximate samples were in the range of 0.7339 to 0.8658 (Table 12). Archaic samples from Plains, southeast U.S. and Florida were distant from the Kennewick individual, with zero probability of

Kennewick having been drawn from these groups. The Kennewick individual was much closer ($D^2 = 5.37$; $p_{typicality} = 0.865132$) to Archaic individuals from the northern Great Basin.

Initially, the above results would suggest rejection of the second null hypothesis. On removal of some of the smaller samples (those with $n < 5$) in the Hanihara data set, we observed that the set of population relationships changed considerably, and suggested that the results presented in Table 12 may be an artifact of pooling the within-group covariances of these many small samples. When the pooled within-groups covariance matrix in the Mahalanobis distance is computed, samples with deviant covariances may skew the resulting distances. To examine this possibility, the Howells-Hanihara reference data were tested for univariate and multivariate normality. The results indicated that 10 of 14 variables were not univariate normal, and the pooled data were not multivariate normally distributed. Thus the previous results (Table 12) are somewhat suspect.

In order to minimize the effect of outlying populations on the pooled within-groups covariance matrix, we elected to combine the 277 individual samples into eight major geographic groups: Africa, Europe, the Near East, Northeast Asia, Southeast Asia, the Americas, Australia, and Polynesia. A combined Ainu/Jomon sample was retained separately. The resulting regional data were univariate normally distributed (but exhibited some multivariate leptokurtosis) and appear to provide a better overall approximation of world-wide craniometric variation than the use of individual modern samples. Because sample sizes for some of the Archaic reference data were small, we utilized the pooled within-group covariance matrix derived from eight modern regional samples to calculate Mahalanobis distances for Kennewick and all Archaic populations, following the suggestion of Jantz and Owsley (1997) and Van Vark and Schaafsma (1992). This avoided the possibility that the small Archaic samples would also skew the results. Table 13 provides the resulting typicality probabilities for the ten size-corrected variables. In this analysis, the Kennewick individual is most similar to the Archaic sample from Indian Knoll, Kentucky, followed by the Ainu/Jomon pooled sample, an Amerindian pooled sample, Northeast Asians, and Southeast Asians (Table 13). Once multivariate normality in the reference data was established, the morphological similarity between Kennewick and Archaic groups is stronger. The typicality probability of Kennewick having been drawn from either middle Holocene sample from the eastern U.S. ($p_{typicality} = 0.\ 873325$) is high, followed by the Ainu/Jomon groups of east Asia ($p_{typicality} = 0.\ 476220$) and the pooled hemispheric American Indian sample ($p_{typicality} = 0.\ 450143$). Other Archaic groups not shown in Table 13 also exhibit higher typicality probabilities (0.5999 to 0.1369); the seven remaining modern regional samples exhibit lower typicalities, in the range of 0.0040 to 0.1734. These results support the contention that there is at least some morphological similarity between Kennewick and Archaic groups, although the Archaic samples from the southeastern U.S. are clearly distinct. Based on these results, it is not possible to reject the second null hypothesis.

In addition to multivariate craniometric analysis, we also performed a set of bivariate analyses that utilize naso-orbital indices derived by Gill (1984) for discriminating American Whites from Plains Indians and American Blacks. The Kennewick remains produced a maxillofrontal index of 46.9, a zygoorbital index of 30.9, and an alpha index of 72.7. Based on these data, two of Kennewick's indices (maxillofrontal and alpha) fall above the non-white/white cutoff point, suggesting that Kennewick's nasal and orbital configurations for those dimensions are most similar to Gill's (1984) American White sample. The third index (zygoorbital) is well within the Plains Indian/Black range and suggests that Kennewick's zygoorbital breadth and naso-zygoorbital subtense are more similar to Gill's Plains/Black samples.

Odontometric Analyses

Because of excessive dental wear, maximum crown diameter data for Kennewick were limited to seven buccolingual crown diameters: UI1, UC, UM3, LC, LM1, LM2, and LM3. However, because of large numbers of missing variables, only seven of the 14 Wolpoff (1971) samples (N=42) could be used. These data were employed in principal components and discriminant analysis procedures. The first three principal components encompass 69.82% of the total buccolingual variation present in these limited comparative data, and place Kennewick at the margin of prehistoric Amerindians and southeast Asian individuals (Figure 10). The canonical variates was analysis was not significant (p = 0.0561) and will not be presented. The posterior probabilities derived from size-corrected data (not PCA scores) indicated that Kennewick would be classified as part of the largest sample, prehistoric Amerindians from Dickson Mound ($p_{posterior}$ = 0.4584); typicality probabilities were highest for Dickson Mound, followed by Europeans and Southeast Asians (Table 14). Typicality probabilities for including with other prehistoric Amerindians (a composite sample from several North American sites) were low ($p_{typicality}$ = 0.1711).

Discrete Trait Analysis:

Cranial and dental discrete traits presented a difficulty in analysis. These features could only be scored as "present" or "absent" in Kennewick, while they are recorded as a percentage of "presence" or "absence" in comparative samples. In order to statistically assess the Kennewick discrete data, we elected to follow a procedure outlined in Powell (1993) for converting frequency data to presence/absence form in statistical analyses. All comparative sample frequencies were converted to a set of ones or zeros following Powell (1993), and these data were then used to generate posterior probabilities of group membership for an unknown sample using logistical discrimination (Jobson 1982). Typicality probabilities were not generated for these analysis, though such an approach would be possible.

Cranial discrete data for eight variables in 20 world-wide samples provided a statistically significant discrimination (log-likelihood chi-square 24.93 at 7 d.f., p = 0.0008) of samples into "Amerindian" and "Non-Amerindian" groups. Under this method, Kennewick had a probability of 0.0000 for membership in Amerindians and 0.9998 for membership in Non-Amerindians. The procedure was repeated using dichotomized dental data. In this analysis, 44 samples were divided into Sinodont (including American Indians) and Sundadont groups. The discriminatory power of this method was significant (log-likelihood chi-square 43.360 with 7 d.f, p = 0.0001) for the dental data. Kennewick had a probability of 0.48460 for membership in the Sinodont group, 0.93769 for membership in the Sundadont group. The analysis was repeated using a third group, composed of Paleoindian and middle Holocene samples, in addition to the Sinodont and Sundadont populations. Early Holocene American samples were separated from the main east Asian dental patterns because they exhibit a mixture of features that occur in high frequency in both Sinodonts and Sundadonts (see Powell in press and Powell 1995). Based on this analysis, the Kennewick specimen had a posterior probability of 0.0055 for membership in Sinodonts, 0.5940 for membership in Sundadonts, and 0.4005 for membership in the early Holocene group.

Anthroposcopic Trait Analysis:

Analysis of Kennewick's craniofacial features proceeded as in other forensic cases examined by Rose and Powell. Kennewick was scored for a number of anthroposcopic features, following Rhine (1990), Napoli and Birkby (1990), Brues (1990), Gill and Gilbert (1990), and Brooks et al. (1990).

The craniofacial appearance of Kennewick contains a mix of features observed in both Amerindian and American White populations from forensic contexts.

Kennewick's more European/Caucasoid features included cranial sutures of medium complexity (where observable), no wormian bones (where observable), no *os japonicum*, a large nasal spine, slanting ascending ramus profile, and an undulating horizontal ramus border. Native American/Mongoloid features included a large malar tubercle, blurred nasal sill, zygomatic posterior tubercle, slight nasal depression, moderate prognathism, elliptical dental arcade, straight palatine suture, and what appeared to be an angled zygomaticomaxillary suture (though much of this was obliterated by sutural fusion and damage). Kennewick also exhibits forward facing frontal processes of the Maxilla (Gill and Gilbert 1990) typical of modern American Indians. The Kennewick facial skeleton also exhibited features that occur in several modern non-Amerindian populations, including a nasal bone configuration intermediate between towered and tented forms, a medium nasal opening, vertical zygomatic bones, a somewhat rhomboid orbital shape. Many of these features are typical of Polynesian groups. Kennewick lacked the projecting and bilobate chin of Europeans.

The midfacial profile of Kennewick was examined following Brooks et al. (1990). Kennewick exhibits a slight concavity below the prominent anterior nasal spine, followed by minimal prognathism and a more vertical outline approaching infradentale superior. This condition is intermediate between the American Whites, which tend to have a less prognathic profile and a much shorter outline, and the North American Indian profiles (particularly those from the northern Great Basin such as Brooks et al. 1990 Figure 3a), which tend to be concavoconvex (Brooks et al. 1990).

Based on CT data, the oval window of the external auditory meatus is partially visible, a condition that occurs in only 6% of Caucasoids (American Whites), but occurs in 34% of Mongoloid (Native American) and 32% of admixed (Hispanic/Mestizo) individuals. The posterior wall morphology of the external auditory meatus is convex, which is found in 82% of Caucasoids (American Whites), and in 44% and 73% of Mongoloid and admixed populations (Napoli and Birkby 1990). The temporopetrous angle of inclination in Kennewick was significantly smaller (19°) than that of Caucasoids (32.07°) and admixed (32.44°) groups.

Overall, the anthroposcopic data indicate that the Kennewick skeleton contains a mix of features seen in modern groups, including East Asians, American Indians, and Europeans. The skull lacks features associated with African populations. Gill (1986) presented a list of features for geographic races, and noted that the Polynesian sample (primarily from Easter Island) exhibited a wide range of features like those in Kennewick. Such a finding corresponds to the stronger south Pacific and Polynesian morphometric appearance the Kennewick skull noted in the craniometric analyses.

Summary

The Kennewick skeleton is a male who died between 45 and 50 years of age. He was approximately 175 cm (5' 9") tall, based on an average of all stature estimates. The morphology of the humeri and muscle marking of all arm bones indicate that he was well-muscled and engaged in rigorous activity employing his arms. The left elbow joint reaction area is also associated with this rigorous activity. All evidence for arthritis is minor and all joints are in excellent shape for a man of his age. He most likely would not have experienced any pain or problems with any of his joints. Many years prior to death he had broken two right ribs which did not heal together and formed pseudoarthroses (false joints). These false joints would not have caused any disability or pain. Possibly at the same age he also suffered a fracture of the right humerus. This healed well and would have caused no disability. Many years before death and probably when he was a teenager (and at the same time as the other trauma), an accident or conflict occurred which resulted in a projectile point being embedded within the right iliac blade of the pelvis. Recovery from this wound was complete; there was no infection of the bone, and there was no disability associated with this injury. The small defect of the frontal bone of the skull would have occurred just before death. This defect is obscured by matrix both within the depression and the inner surface of the skull that makes definitive interpretation impossible. However, there is no evidence for a depressed fracture and this is most likely a minor traumatic event.

Taphonomically, the Kennewick remains represent a single individual who was most probably interred rather than left to decompose on the surface. The completeness of the remains, the lack of carnivore damage to the remains, and presence of rodent gnawing on several elements are all typical of the pattern seen in intentional modern and prehistoric burials. In fact, the Kennewick remains could not be statistically distinguished from intentionally buried remains, but could be distinguished from human remains in other post-depositional contexts (Table 4). The red staining of some bones ***may*** be cultural in origin, suggesting application of red ochre pigment to the skin of the individual prior to interment. This determination will require confirmation of iron oxide levels in the matrix adhering to the bone, and possibly chemical analysis of the bone itself. Algal staining on some elements is probably due to exposure of the remains in shallow water just prior to their recovery in along the Columbia River.

Like other early American skeletons, the Kennewick remains exhibit a number of morphological features that are not found in modern populations. For all craniometric dimensions, the typicality probabilities of membership in modern populations were zero, indicating that Kennewick is unlike any of the reference samples used. Even when the least-conservative inter-individual distances are used to construct typicality probabilities, Kennewick has a low probability of membership in any of the late Holocene reference samples. Similar results were obtained by Ozolins et al. (1997) for Upper Paleolithic samples from Asia, Africa, and Europe and Paleoindian groups, and are not surprising considering that Kennewick is separated by roughly 8,000 years from most of the reference samples in Howells (1989) and Hanihara (1996). The most craniometrically similar samples appeared to be those from the south Pacific and Polynesia as well as the Ainu of Japan, a pattern observed in other studies of early American crania from North and South America (Steele and Powell 1992, 1994; Jantz and Owsley 1997).

Only in three cases, including two analyses based on the least-conservative inter-individual distances, was a Native American included in the five closest samples to Kennewick. The Hanihara craniometrics and the cranial discrete traits both failed to find an association between Kennewick and modern Indian groups, despite the fact that these data sets included populations from the Northwest Coast and Interior Plateau regions of North America. Only the odontometric data suggested a connection between Kennewick and modern American Indians, but the typicality probabilities for this analysis were all very low. Clearly the Kennewick individual is unique relative to recent American Indians, and finds its closest association with groups of Polynesia and the Ainu of Japan.

The question of "Caucasoid" affinities for the Kennewick remains can be addressed, depending on how the term "Caucasoid" is defined. In the strictest sense, this refers to populations of western and southwest Eurasia-- peoples that live or lived in what is now Europe, the near East, and India. When defined in this way, Kennewick is clearly not a Caucasoid. Although one European group, Zalavar (1/25 = 4%) was included among the five nearest "neighbors" to Kennewick (Tables 7 - 12), the majority of nearest neighbors are from Polynesia (16/25 = 64%) and east Asia (24%). The Ainu, which we have described as "east Asian", occur as a nearest neighbor three times (12%), while Native Americans occur as neighbors just twice (8%). Although Kennewick exhibits some features that typically (but not exclusively) occur in modern American Whites (Caucasoids), these same features also occur in moderate to high frequency among Polynesian populations (Gill 1986). If the Ainu are considered to be "Caucasoids," as they were first described in 19th-century anthropological literature, this might explain reports of "Caucasoid" features in the Kennewick skull. However, we follow Brace and Hunt (1990) and Turner (1990) in viewing the Ainu as a southeast Asian population derived from early Jomon peoples of Japan, who have their closest biological affinity with south Asians rather than western Eurasian peoples. Thus Kennewick appears to have strongest morphological affinities with populations in Polynesia and southern Asia, and not with American Indians or Europeans in the reference samples.

Going back to the original null hypothesis, we can reject this hypothesis for the craniometric data, for cranial discrete traits, and for dental discrete traits. The data are inconclusive for anthroposcopic traits, and the null hypothesis cannot be rejected for the odontometric data. The Kennewick skeleton can be excluded, on the basis of dental and cranial morphology, from recent American Indians. More importantly, it can be excluded (on the basis of typicality probabilities) from ***all*** late Holocene human groups. There are indications, however, that the Kennewick cranium is morphologically similar to Archaic populations from the northern Great Basin region, and to large Archaic populations in the eastern woodlands. While these data raise a number of interesting questions, only a regional time series analysis of a sequence of well-dated human remains from east-central Washington spanning the past 9,000 can provide direct evidence of biological continuity between Kennewick and modern American Indian tribes.

Table of Contents | References Cited

EXPLORE | CONSERVE | PEOPLES & CULTURES | COMPUTE | IN THE PARKS

Home | Publications | Laws | Search | E-mail | Links to the Past

Last Modified: Wed, Nov 17 1999 01:23:38 pm EDT

MJB

ParkNet
National Park Service