REPORTS

THE RECOVERY AND FIRST ANALYSIS OF AN EARLY HOLOCENE HUMAN SKELETON FROM KENNEWICK, WASHINGTON

James C. Chatters

The nearly-complete, well-preserved skeleton of a Paleoamerican male was found by chance near Kennewick, Washington, in 1996. Although analysis was quickly suspended by the U.S. government, initial osteological, archaeological, and geological studies provide a glimpse into the age and life of this individual. A radiocarbon age of 8410 ± 60 B.P., stratigraphic position in a widely-dated alluvial terrace, and an early-Cascade style projectile point healed into the pelvis date the find to the late Early Holocene. Initial osteological analysis describes the man as middle-aged, standing 173.1 ± 3.6 cm tall and weighing approximately 70–75 kg. Healthy as a child, he later suffered repeatedly from injuries to his skull, left arm, chest, and hip, in addition to minor osteoarthritis and periodontal disease. His physical features, teeth, and skeletal measurements show him to be an outlier relative to modern human populations, but place him closer to Pacific Islanders and Ainu than to Late Prehistoric Amerinds or any other modern group. Despite his uniqueness relative to modern peoples, he is not significantly different from other Paleoamerican males in most characteristics.

El esqueleto preservado y casi completo de un hombre paleoamericano fue descubierto por casualidad cerca de Kennewick, Washington, en 1996. Aunque el análisis fue rapidamente suspendido por el gobierno de los Estados Unidos, estudios osteológicos, arqueológicos, y geológicos iniciales proveen información sobre la edad y vida de este individuo. Una edad radiocarbónica de 840 ± 60 A.P., la posición estratigráfica en una terraza aluvial de edad conocida, y una punta de proyectil de estilo Cascade temprano en la pelvis datan este hallazgo al Holoceno temprano. El análisis osteológico inicial describe a un hombre de edad media, de173.1 ± 3.6 cm de alto y de 70–75 kg de peso. Sus rasgos fisicos, dientes, y mediadas esqueletales lo ponen más cerca de los habitantes de las islas pacíficas que de los amerindios prehistóricos tardíos o de cualquier otra población moderna. Sano en su juventud, el sufrió heridas en su cráneo, brazo izquierdo, pehco, y cadera, además de osteoartritis y enfermedad periodontal. No se ha determinado la causa de su muerte, pero sus hueso proveen un visión rara y pasajera de la vida de los paleoamericanos y sugiere preguntas sobre la complejidad y el tiempo del poblamiento de América.

The peopling of the Americas is the most prominent and contentious archaeological issue in the Western Hemisphere. A large and rapidly growing body of literature addresses where the immigrants came from, how they made the trip, when they arrived, what technologies they possessed, and who they were (e.g., Bonnichsen and Steele 1994; Dillehay and Meltzer 1991; Laughlin and Harper 1979; West 1996a). Research into the "who" question has largely been focused on the genetic traits and languages of modern peoples (e.g. Cavalli-Sforza et al. 1994; Greenberg et al. 1986) in an attempt to reconstruct history from its end point. Actual physical remains have largely been ignored, partly because they are so rare and partly because of a prevailing view that early skeletal material was indistinguishable from later Amerindians (Hrdlicka 1937). Within the past decade, however, study after study of Paleoamerican skeletal material is showing not only that early people are physically distinct from their modern counterparts (Jantz and Owsley 1997, 1998; Neves and Pucciarelli 1989, 1991; Steele and Powell 1992, 1994), but also that the earliest remains are unexpectedly diverse (Jantz and Owsley 1998; Neves et al. 1996).

Unfortunately, most of these studies remain limited by the tiny sample of ancient skeletal material. Whereas there are tens of thousands of North Amer-

---

James C. Chatters ■ Applied Paleoscience, 648 Saint St., Richland, WA 99352, and Department of Anthropology, Central Washington University, Ellensburg WA 98926, email: paleosci@owt.com.

American Antiquity, 65(2), 2000, pp. 291–316

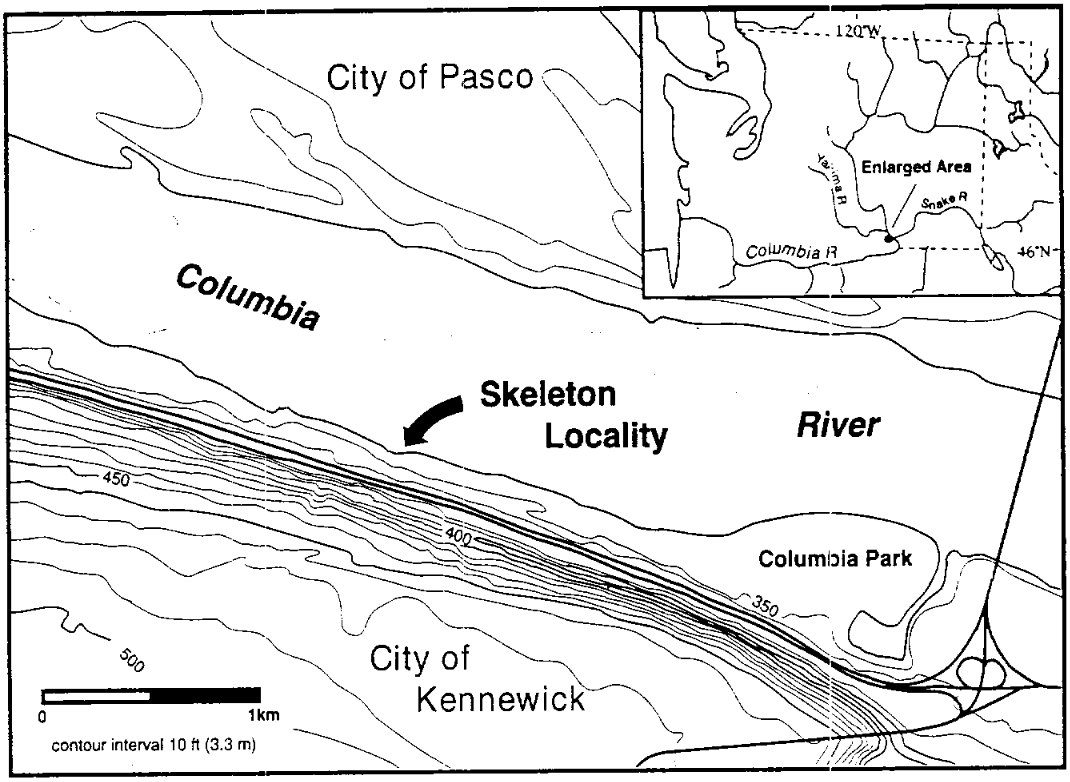

Figure 1. Topographic map showing the locality where the Kennewick skeleton was found.

ican skeletons dating to the past 2,000–3,000 years, no more than 37 individuals predate 8000 B.P. Accepting the earliest arrival at sometime before 14,000 years ago (Fiedel 1999) and calibrating 8000 B.P. to ca. 9000 years, this is an average of 8 individuals per thousand years. The number of complete skeletons and fully measurable crania thus far discovered is no more than 10. The opportunity to add one more—to increase the number by 10 percent—arose and nearly disappeared with a recent discovery in the eastern Washington town of Kennewick.

In July 1996, the nearly complete, well-preserved skeleton of what later proved to be an Early-Holocene Paleoamerican was discovered by spectators during a hydroplane race. The coroner of Benton County, Washington, in whose jurisdiction the bones were found, called on me to conduct a forensic investigation. The remains appeared to resemble modern western Eurasians more than recent Amerinds and were associated with debris from a late nineteenth- to early twentieth-century homestead. However, a stone projectile point was embedded in the pelvis, putting the individual's affiliation in doubt. A radiocarbon date was ordered on bone from the skeleton to solve the conundrum and established the Early-Holocene age. Soon thereafter, all studies were ordered to a halt by the U. S. Army Corps of Engineers (COE), from whose land the skeleton had eroded. Within two weeks the COE announced its intent to repatriate the remains to five local tribes, but the action was halted when Robson Bonnichsen, C. Loring Brace, George Gill, C. Vance Haynes Jr., Richard Jantz, Douglas Owsley, Dennis Stanford, and D. Gentry Steele filed suit. At this writing, the case remains unresolved.

This paper describes the recovery, treatment, and initial analysis of the remains now popularly known as Kennewick Man.

The Site

Human bones were discovered at the base of a 2-m-high cutbank on the shore of a 6.4-km-long public area known as Columbia Park (Figures 1 and 2). The remains were disarticulated and scattered, clearly having eroded from a collapsed portion of the cut bank, and were distributed along more than 30 m of beach (Figure 3). Bones lay in the soft, secondary mud of the reservoir, often seeming to float at the

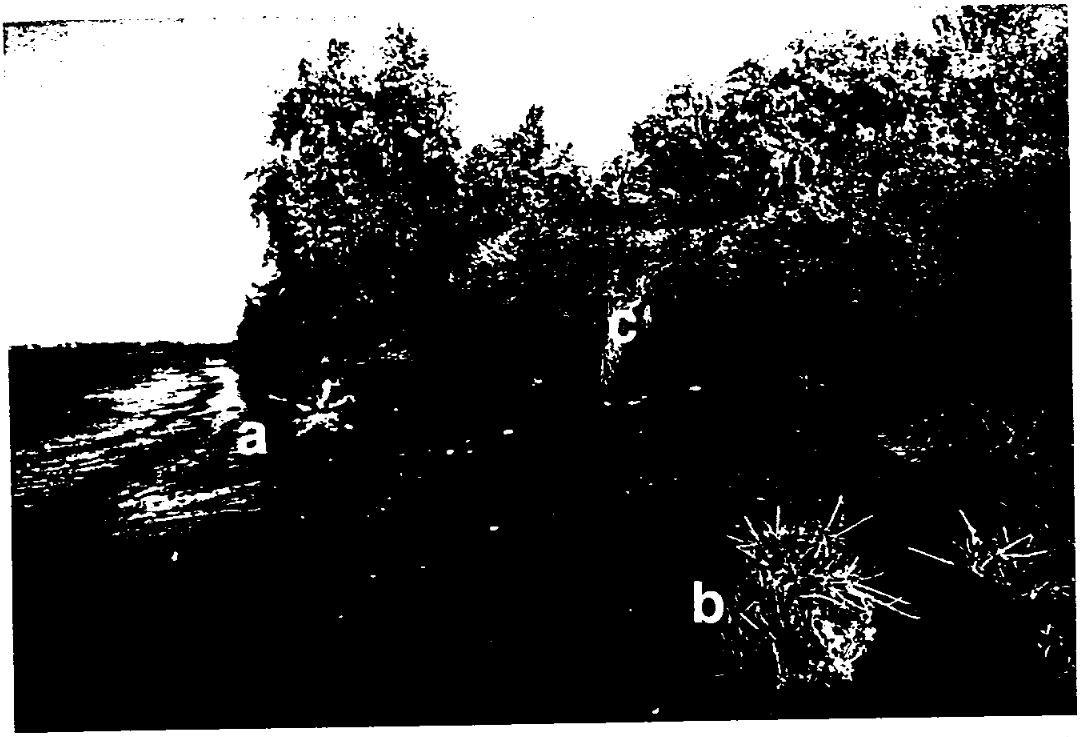

Figure 2. The Kennewick Man Site, looking east. The skull was reported found near (a), and most fragments were scattered between (a) and (b). (c) marks the location of the profile in Figure 4.

water-mud contact. All larger fragments, including the skull, longbones, scapulae, os coxae, complete vertebrae, and larger rib and foot bones, occurred in the 12-m area between two prominent grass tussocks (a to b in Figure 2). Smaller bone fragments also were concentrated in this area, but scattered westward (upstream) for another 20 m. An inspection of the cut bank below which the skull had rested was unrevealing; no in situ bones or evidence of a grave pit could be found, nor was any found during the many later inspections.

The site is located on the right (south) bank of the Columbia River 531 km upstream from the Pacific Ocean (46°15′30″ N. latitude; 119°10′00″ W. longitude) (Figure 1). At an elevation of 104 m, it lies near the center of a broad lowland known as the Columbia Basin. The climate is maritime influenced, but the rain shadow effect of the Cascade Range, to the west, creates semiarid conditions (Jackson 1985) that support a shrub-steppe ecosystem (Franklin and Dyrness 1988). Three great rivers meet within a short distance of the site. The Yakima enters the Columbia 5.5 km upstream and the Snake River joins it 10.3 km downstream. All three are important salmon streams.

The confluence of major rivers, with their water and fish, made the area an important aboriginal center, at least in later times (Ray 1936; Thwaites 1904–1905), and archeological sites are plentiful (Cleveland et al. 1976). The Tri-Cities Archaeological District, which encompasses the area around the Yakima River mouth, contains 20 documented sites, including 6 villages and 5 cemeteries of the Late Period (as defined in Chatters and Pokotylo 1998; see also Ames et al. 1998) and an assortment of campsites of undetermined age. Excavations at one site, opposite the mouth of the Yakima River, revealed deposits dating to the later middle Holocene (Hartmann 1986), but no earlier components have yet been identified.

The remains, although found inside the boundaries of the Tri-Cities Archaeological District, were not within a documented site. The nearest site on the right bank of the Columbia River is 45-BN-52, a now-inundated Late Period village 2.9 km upstream (Galm et al. 1981). On an island adjacent to 45-BN-52 is a Late Period cemetery (45-BN-28), and bones lagged from a second such cemetery were found just downstream of 45-BN-52 shortly after the Kennewick Man discovery. The Washington State Archeologist, Robert Whitlam has recently extended the boundary of 45-BN-52 to encompass the Kennewick Man site, although the two are widely separated in space and time. During geoarchaeological studies in 1997, two additional site areas were observed, also within the new 45-BN-52 boundaries. A single shell midden of middle Holocene age was located 150 m upstream, and a lagged deposit containing the base of a leaf-shaped projectile point was present more than 220 m in the same direction (Wakeley et al. 1998). Thus far, however, no habitation site coeval with the Kennewick skeleton has been identified in the vicinity.

Geoarchaeology

Local Geomorphology

During the late Wisconsinan Glaciation, the Columbia Basin was swept by a series of outburst floods from glacial lakes Missoula and Columbia, which terminated around 11,250 B.P. (Baker et al. 1991). The Missoula events, which were the larger floods, ceased by 12,500–13,000 B.P. (Atwater 1986), while smaller outbursts from Lake Columbia continued (Gough 1995). With the ablation of the Okanogan lobe of the Cordilleran glaciation, the Columbia River, which had been the primary meltwater drain, found itself under-fit for its channel. By 10,000 B.P., it began filling this channel with a fine-textured floodplain that can be identified from the U.S.-Canadian border downstream well beyond the mouth of the Snake River, (Chatters and Hoover 1992; Fryxell and Daugherty 1963). A corresponding structure, identified as the Early Holocene Alluvium, occurs on the Snake River (Hammatt 1977). In most places, fluvial deposition on this landform ceased after 8000 B.P. Eolian sand, which frequently contains a stratum of ash from the 6850 B.P. eruption of Mt. Mazama (Bacon 1983), capped the floodplain as the river underwent a downcutting phase. Floodplain development resumed at a lower elevation by 4000–4300 B.P., creating a deposit that is usually coarser textured and less distinctly bedded than the Early Holocene alluvium.

In the Kennewick vicinity, one can see all four of the major depositional units identified for the region as a whole. The 143-m (470 ft) terrace occupied by the City of Kennewick in Figure 1 represents one or more of the larger Missoula floods and thus predates 12,500 B.P. A second, lower terrace that is not present in Figure 1 occurs along the Yakima River at an elevation of 112 m. Containing fluvially deposited ash from the ca. 11,200 B.P. eruption of Glacier Peak (Mullineaux 1986), it was probably deposited by one of the last Lake Columbia outbursts. The Early Holocene Alluvium is nearly ubiquitous in the Kennewick vicinity and includes the terrace at Columbia Park. The Later-Holocene floodplain is much less extensive, being largely inundated, but is evident as a narrow bench, 1 m below Columbia Park on the opposite side of the Columbia River. Thus, based on geomorphology alone, the Kennewick skeleton had to postdate the Glacier Peak ashfall and initiation of the early Holocene floodplain, or 11,200–10,000 B.P.

Site Stratigraphy

Methods. Geoarchaeological data were collected in 1996 and 1997. In both cases, work was performed under strict government constraints. Samples from the 1996 work have been analyzed texturally to help refine stratification within what appeared to be massive units, identify the stratigraphic source of the skeleton, and evaluate alternative scenarios for the process of skeleton deposition

A single 1.5-m section of cutbank was cleared, described and sampled by COE archaeologist Ray Tracy and me in November 1996. This section was located as close as possible to where the skull had come to rest and was probably the negative from which the block of sediment that contained the skeleton had fallen (Figures 2, 3). A continuous column sample was taken from this section; units were 10 cm thick in the massive upper eolian unit and 5 cm thick in finer, fluvial sediments below that contact.

A second series of profiles was taken during COE-controlled geoarchaeological investigations in December 1997 (Huckleberry et al. 1998). Work was limited to COE-selected 50-cm-wide sections along a 334 m segment of shoreline. Four of these (CPP044, 054, 080, and 093) were in the vicinity of the skeleton locality, but a severe spring flood had eroded the cutbank an average of 2 m from its 1996 position (Figure 3), taking this investigation farther from the probable source of the bones. Thomas W. Stafford (Stafford Research Laboratories) and I were able to profile a section of bank between 084 and 093 and thus obtain some information on stratigraphic continuity, but it was not in immediate proximity to the primary bone concentration. The COE took cores

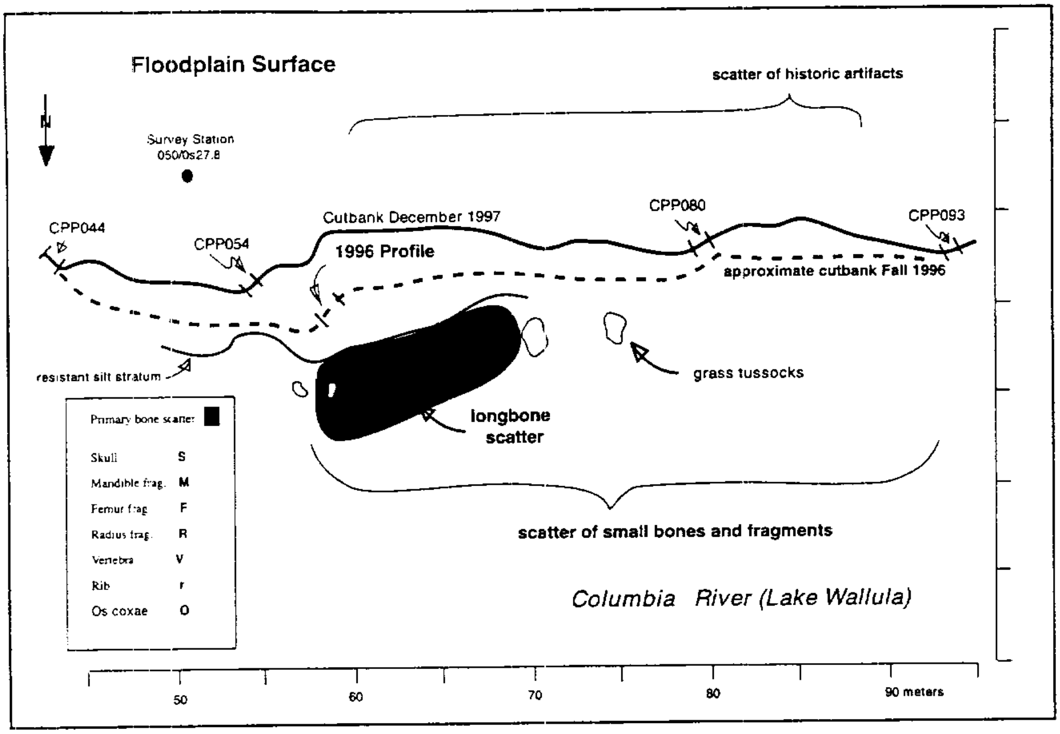

Figure 3. Plan of the Kennewick skeleton locality, showing the approximate locations of elements, the distribution of historic artifacts, and locations of profiles taken in 1996 and 1997. All large fragments and approximately 90% of all bone came from the primary scatter. PC designates the 1997 profile.

from the beach below the cutbank, but the relevance of these to dating or understanding the context of the skeleton is minimal. All sections were profiled and described, and selected sections were sampled for analysis and radiocarbon dating. Altogether, 100 samples were obtained, but these have not yet been analyzed and will be reported elsewhere.

I submitted sediment from bone surfaces and alternating samples from the 1996 profile to the Washington State University Department of Crop and Soil Sciences (DCSS) for textural analysis. Samples were submitted blind, so the analyst could proceed unbiased by foreknowledge of sample sources. DCSS decalcified and disaggregated the samples and ran them on the Mastersizer™ laser system. Results are presented in Table 1.

Results. Stratigraphy of the Kennewick Man Site (Figure 4) is similar to that of other Early Holocene floodplain deposits (Chatters and Hoover 1992; Fryxell and Daugherty 1963; Hammatt 1977). Two major units are recognizable (Huckleberry et al. 1998). The lower, Unit II, consists of at least 4 m of horizontally-bedded fluvial deposits with a tendency to fine upward. No tephra deposits were included. Lying unconformably atop this series is a massive eolian deposit (Unit I) that contains a discontinuous stratum of Mazama tephra in its lower half. The portion of Unit II that lies beneath the beach level is distinctly stratified, but strata are less visually discernible in the upper portion, particularly above 160 cm in the 1996 profile. Textural analysis, however, shows that this section of the profile is finely bedded (Table 1). These uppermost Unit II strata contained amorphous calcite concretions that often exceeded 20 mm in diameter, and were concentrated between 70–100 cm and again at 130–160 cm. Profiles taken in 1997 show only one calcite-rich zone at the top of the fluvial series (Wakeley et al. 1998). These concretions may result from long-term soil formation processes, but it is unclear which surface—the top of the fluvial beds, the slowly accreting eolian deposit, or the modern tread of the terrace—was the active zone.

COE geologists obtained radiocarbon dates on bulk carbon from four fluvial strata below the modern beach level and from two samples of freshwater mussel shell from Unit I. All bulk carbon samples

Table 1. Mean Particle Sizes of Sediment Samples from the 1996 Profile at the Kennewick Man Site Compared with Sediment from the Bone Surfaces.[a]

Unit	Depth from Surface (cm)	Mean Particle Size (mμ)
I	20–30	60.29
	40–50	75.93
	60–65	77.23
II	70–75	52.01
	80–85	*56.98*
	95–100	46.65
	105–110	47.73
	115–120	68.12
	125–130	61.73
	135–140	*59.12*
	145–150	52.13
	155–160	54.32
	165–170	47.97
	175–180	41.97
	200–210[b]	37.73
Skeleton	run 1	58.49
	run 2	63.50
	run 3	56.38

[a] Samples most similar to the skeleton sediment are italicized.
[b] This is from the resistant silt stratum (Figure 4) and is offset horizontally from the other sample by 2 m; depth is estimated as depth below the surface of the primary profile.

underlie the profile in Figure 4. With increasing depth, these dates are 9010 ± 50 (WW-1626), 12,460 ± 50 (WW-1737), 15,330 ± 60 (WW-1627), and 14,560 ± 50 B.P. (WW-1738) (Wakeley et al. 1998). The lowest three dates predate the Glacier Peak ashfall and are clearly too old, which also casts doubt on the uppermost date, despite its general consistency with a position between the Mazama and Glacier Peak ashes. Shell dates from Unit I were 6230 ± 60 (Beta 113838) and 6090 ± 80 B.P. (Beta 113997) (Wakeley et al. 1998), which is consistent with their stratigraphic position.

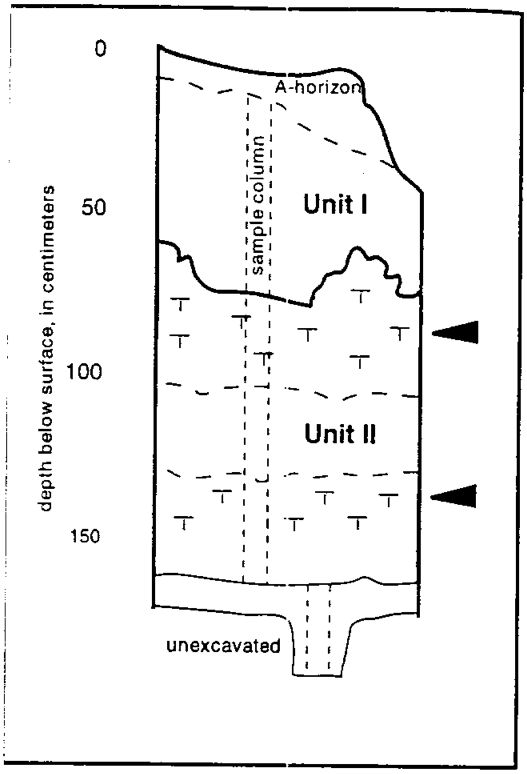

Figure 4. The 1996 sediment profile, taken at the negative from which the Kennewick skeleton fell (Figure 1C), showing the location of the sample column and marking the two concretion-rich zones that most closely compare with sediment from the bone surfaces (arrows).

Stratigraphic Position of the Skeleton

The skeleton certainly slumped from the upper 180 cm of the floodplain. Calcite-cemented concretions were abundant on the bones and, since these do not occur in Unit I, the remains must have lain somewhere in Unit II. Texturally (Table 1, Figure 5), sediment from the skeleton compared most closely with samples from the 80–85 and 135–140 cm levels, which are within the concretion-rich zones. Strata below 160 cm are ruled out by their very fine textures; those above 65 cm (Unit I) by their coarser textures. Which unit is the closer match to the concretions from the skeleton is unclear, however. When mean particle size is used as a criterion (Table 1), the 135–140 cm sample is the closest match; when textural profiles are used, the skeleton sample more closely resembles the 80–85 cm sample (Figure 5). My collaborators and I have undertaken mineralogical analysis in the hope of pinpointing the source of the skeleton. In any case, it is clear that the bones eroded from the uppermost meter of Unit II. Recent studies have tended to confirm this assessment (Huckleberry and Stein 1999).

Interment or Natural Deposition

In the absence of a burial pit and associated grave goods, we do not know whether the skeleton was intentionally buried or incorporated in a fluvial deposit. However, the comparison of sediment from the bones with *in situ* strata provides some clues. If the depositional process was intentional burial in a stratified sedimentary setting, then we would expect the soil from the bone surfaces to represent a mix of strata; no clear match would be expected to a single

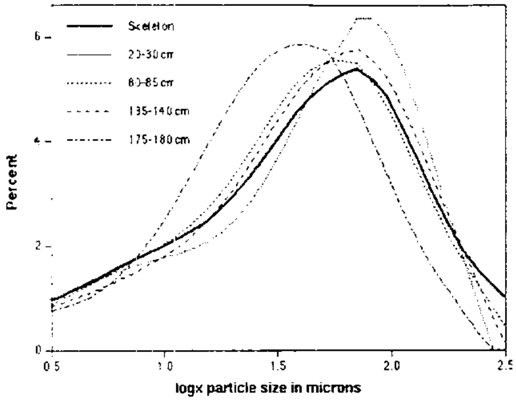

Figure 5. A comparison of the textural profiles in the 3 to 300 micron range for five sediment samples from the Kennewick Man Site. A close similarity is evident between the skeleton sample and samples from 80–85 and 135–140 cm. Despite its similar mean particle size (Table 1), the 20–30 cm sample is clearly distinct. The tail forming at the right of the skeleton profile probably represents pseudosand from silica concretions.

stratum. If fluvial deposition was the process, then we *would* expect such a match. The result, as we see in Table 1 and Figure 5 is again somewhat ambiguous, but the data do seem to lean toward the single-stratum, fluvial deposition hypothesis. Countering this interpretation, however, are two seemingly irreconcilable facts. First, the skeleton is unusually well preserved. Second, textural data in Table 1 indicate that the fluvial strata are typically less than 20 cm thick. It would seem that shallow deposits and good preservation are unlikely partners. However, we know neither how much time elapsed between deposition events nor, because of the secondary context, the topography of the surface onto which the skeleton might have been laid. Rapid deposition and/or deposition in a sediment trap of any kind, whether a depression, bush, or mass of debris, could have led to burial deep enough for good preservation. The issue remains unresolved.

Artifacts

Hundreds of artifacts littered the discovery site, but only one was found in direct, unquestionable association with the Kennewick skeleton. Most artifacts were historic and had eroded from a shallow stratum that was visible in the cutbank between approximately 65 and 90 m west (Figure 3). Sawn bone, ceramic and glass shards, rusted metal, square nails, and horseshoes were scattered along the beach, often lying among the bone fragments. The handle of a pewter-inlaid knife found among the bones appeared initially to fit a depression in the distal left femur. A small amount of lithic debitage, including flakes of opal, basalt, and quartzite, and a few fire-cracked and flaked cobbles were loosely scattered among the beach lag, primarily more than 10 m downstream of the skeleton. No lithics were seen eroding from the cutbank at any time.

Neither historic objects nor lithics can be linked to the skeleton. The radiocarbon age on the bone (see below) precludes the historic material; the association of the bone-handled knife with the femur later proved to be spurious. A thin scatter of lithics, fire-cracked rock, and mussel shell is nearly ubiquitous along the Early-Holocene floodplain in the Mid-Columbia region, which makes such material of little moment for interpreting this particular case. A small amount of lithics and shell was found *in situ* during 1997 geoarchaeological work, but all of it was from Unit I and occurred at some distance from the skeleton locality (Wakeley et al. 1998).

The Projectile Point

The only cultural object found in direct association with the Kennewick skeleton is the fragmentary projectile point embedded in his pelvis. The surfaces of the point were visible through two bone windows, one in either surface of the ilium (Figure 6). The edges were largely, but not entirely, obscured by bone. Segments of edge could be seen along the upper rim of the posterior window (Figure 7) and along a portion of the lower rim of the anterior window, at the base of the point. Because it was so extensively obscured, the point's shape, cross-section, and measurements could only be determined radiographically. Multiple X-ray "slices" were taken with a Picker® CT scan parallel and perpendicular to the plane of the blade at 1-mm intervals for a plan view and cross-section (Figure 8). Because object edges are somewhat blurred in the CT scans, measurements based on the radiographs must be understood to be approximate to within 1 mm.

The projectile point is leaf-shaped and made from a siliceous gray stone that appears to be of igneous origin, probably andesite or dacite. It has a narrow, slightly convex, apparently edge-ground basal margin, ca 10 mm wide, and expands to a maximum width of 18 mm near the broken blade edge. The cross-section is plano-convex in some areas to biconvex in others, with a maximum thickness of 6 mm.

Figure 6. Ventral view of the right os coxæ, showing the projectile wound at upper left.

The entire visible edge of the blade is serrated, beginning within a few millimeters of the basal margin. Additional serrations are visible in some CT scan views, indicating the blade edge was completely serrated. The distal end of the blade is impact fractured into an irregular, chisel-like edge. That is, it is sheared-off obliquely to the (cross-section) but perpendicular to the long axis of the blade.

In summary, this is a fragment of a long, broad, thin, leaf-shaped point with a distally expanding blade, sharp, serrated edges and a slightly convex base. When complete, it would have been at least 70 mm long. This point fits the definition of a Cascade Point (Butler 1961), a willow-leaf type often with serrated edges and a plano- convex cross-section. It is the hallmark of the local Cascade Phase (Leonhardy and Rice 1970), which dates between 5000 and 8000 B.P., although some similar forms persist into the Historic period in some parts of the Northwest. Serrated variants of the type dominate components of the Cascade Phase that predate the Mazama ashfall (e.g. Butler 1962; Shiner 1961). If we go by the reservoir-corrected age of the skeleton, the radiocarbon date and projectile point style together place the Kennewick skeleton at the very beginning of the Cascade Phase (see Bense 1972).

The impact fracture and depth of penetration of the point indicate that it was attached to a high velocity weapon. In arrow wounds there is a tendency for the tip of the point to be shattered on impact with bone and apparently remain in soft tissue. The blade, driven by the weight of the shaft, then penetrates bone. Since the bow and arrow were not introduced to the Columbia Plateau until 2400 B.P. at the earliest (Chatters and Pokotylo 1998) this point was almost certainly the tip of an atlatl-propelled dart.

Chronology

Age of the skeleton can be established relatively by stratigraphy and artifact chronology, and absolutely by the radiocarbon date on the bone itself. All evidence is consistent with an early Holocene age.

Relative Age

Geologic and cultural dates overlap. The remains came from the uppermost meter of the Early-Holocene alluvium, deposition of which ceased well before deposition of the eolian sediment of Unit 1.

Figure 7. Close-up of the superior edge of the projectile point from the ventral side. Note serrations.

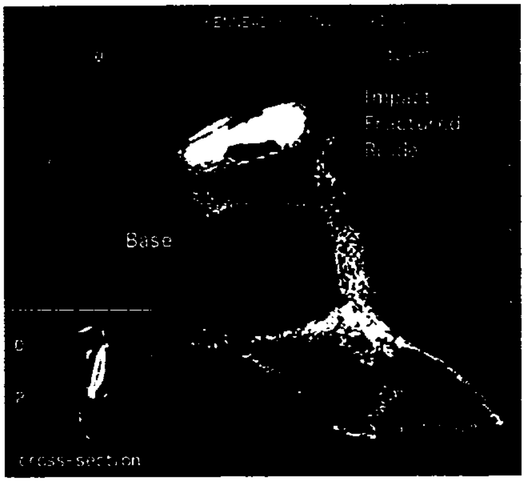

Figure 8. CT scanned plan and cross-section of the projectile point, showing a slightly convex base and fractured distal end. View is from the ventral side.

As noted above, this alluvium ordinarily dates between 10,000 and 8,000 B.P. Locally, deposition certainly commenced after 11,200 B.P. and ceased well before the 6850 B.P. age of the Mazama tephra. The projectile point is of the Cascade style, which begins at ca 8000 B.P.; its serrations indicate a pre-6850 B.P. date. Thus, the skeleton comes from the period of overlap between these chronologies, or close to 8000 B.P.

Radiocarbon Age

A single radiocarbon date on bone collagen has been obtained for the Kennewick skeleton. As part of the Coroner's initial investigation, the fifth metacarpal of the left hand was submitted to the University of California, Riverside for ^{14}C dating. This bone was chosen because it had come from inside the neurocranium, where it presumably had been moved by rodents, and lacked the mineral deposits found on all other bone fragments. Free of precipitates, it apparently had been shielded from percolating water, and was, therefore, the most likely element to retain intact collagen and lack contaminants. Graphite prepared from total amino acids was submitted to Lawrence Livermore National Laboratory and produced an isotopically-corrected date of 8410 ± 60 B.P. (UCR3476/CAMS-29578) with a -^{13}C of -14.9 per mil (Table 2) (Taylor et al. 1998). If we assume, as Taylor et al. (1998) suggest, that the carbon isotope signature results from the intake of marine protein and not C4 plants (an assumption we would need nitrogen isotope information to confirm), a value of -14.9 per mil indicates approximately 70 percent of the man's protein came from marine fish, in this case probably salmon or steelhead (*Oncorhynchus* spp.). If we further assume that the marine reservoir effect has remained constant during the Holocene, then the correction corresponding to this dietary fraction is 530 ± 150 years. The actual radiocarbon age would thus be 7880 ± 160 years B.P., which calibrates to 8340 to 9200 cal. years ago (2 sigma) (Taylor et al. 1998). Until evidence is obtained confirming either of the assumptions, however, it would be prudent to continue to cite the uncorrected age, with caveats.

The Skeleton

Recovery and Treatment

Remains were collected by me and various helpers on ten occasions between July 28 and August 29,

Table 2. Radiocarbon Age of the Bone from the Kennewick Skeleton.

Lab. Number	Conventional	∂^{13}C	Isotopically Corrected	Reservoir Corrected	Calibrated[a]
UCR3476/CAMS-29578	8370 ± 60 B.P.	-14.9 ‰	8410 ± 60 B.P.	7880 ± 160 B.P.	9330–9580 c.y.a.

[a] Calculated using Oxcal 3 and based on isotopically-corrected age for reasons explained in text.

operating under an Archaeological Resources Protection Act permit (DACW68-4-9640) issued by the COE[1]. After the initial collection of surface bone, an attempt was made to water-screen sediments for greater recovery. This proved to be inefficient and risked breakage to delicate fragments, so buckets of water were used instead to wash the mud down to a resistant silt stratum that marked *in-situ* geologic deposits. This hydraulic recovery was used on two occasions and confined to the shaded area in Figure 3. Elsewhere and on all other occasions, recovery entailed surface collecting fragments from beach lag. Because of the clearly-secondary nature of the bone scatter, no attempt was made to maintain precise provenience information.

Bones were taken to the Applied Paleoscience laboratory, where saturated fragments were first laid out to drain. Objects were then placed singly or in groups in large plastic bags that were kept partially open. This allowed moisture to evaporate, while keeping humidity around the bones high enough to retard cracking. Once adhering sediment had dried, it was brushed away. Many of the bones, particularly those in the legs and skull, had adhering calcite concretions and most bones had an infilling of such material. An attempt was made at first to remove the calcite mechanically, but when this appeared to remove the outermost surface of cortical bone, the practice was quickly abandoned. In some cases, concretions fell from the bones after differential shrinkage broke their bonds, and these were collected for later study. Dilute hydrochloric acid was used on one occasion to remove concretions that enclosed a projectile point in the pelvis and masked evidence of new bone growth.

Foreign substances were generally eschewed to avoid criticism for desecrating the remains, regardless of whose they might turn out to be. Nonetheless, polymers were used on three occasions. First, when small drying cracks began to form in the neurocranium and some teeth, a diluted water base polymer (Minwax Polycrylic®) was used to stabilize the bone and broad rubber bands were placed on the neurocranium to help the bone hold its shape. Second, to facilitate measurement and photodocumentation, bones of the face, mandible, and the left humerus were reconstructed using Elmer's® glue. Finally, to produce a mold of the skull, the treated bone was sprayed with Synair Corporation's Synlube 531® release agent, which prevented sticking of a Synair Pour-a-Mold®, polyurethane blanket mold. The blanket mold was stabilized by a mother mold of casting plaster[2]. Third molars were neither treated nor cast, to keep them uncontaminated for potential future analysis.

Documentation

Documents on the remains take the form of written notes, measurements, photographs, X-rays, CT scans, a videotape, and the cast. Measurements of the postcranial material (Table 3) and partial measurements of the skull (Table 4) were initially taken following Bass (1987) using spreading and sliding calipers. Howells (1973; 1989) is the basis for a more complete set of craniofacial measurements from the first generation cast, for which a radiometer and sliding, spreading, and coordinate calipers were used. The original measurements compare closely with those of the cast in all cases but three. The orbital breadth measurements do not match because of differences between Bass and Howell's measurement techniques. The other two cases, nasal breadth and basion-bregma height, probably differ due to original errors in measurement or transcription. I have since checked these values against high-resolution scaled photographs, and find the cast numbers to be the more accurate. Discrete traits of the skull and humerus were recorded following (Buikstra and Ubelacker 1994) from photographs, the cast, and direct observation of the skull (Table 5). Photos were taken in color and black and white of the skull, dentition, assembled skeleton, and pathologies and traumas. X-rays were produced of the right ilium and both distal femora, the former to inspect the embedded object and the latter to look for Harris lines and evidence of osteoporosis. Dental X-rays were obtained to assess tooth root numbers and explore for evidence of pathology. The primary purpose of CT scans was to get a clearer view of an object in the right ilium, but the opportunity also was used to collect cross-sections of the right femur and both humeri as part of an ongoing biomechanical research project (following Ruff 1992). The entire postcranial skeleton, and rib, humeus, and pelvic injuries were videotaped in lieu of detailed photographs.[3] The mold was produced in eight pieces, three for the mandible and five for the cranium, to allow other researchers to reconstruct the skull themselves, rather than force them to accept my interpretation.[4]

Table 3. Cranial Measurements from the Kennewick Skeleton in mm.

	From Original Bone[a]	From 1st Generation Cast[b]
Glabella-occipital length	190	189
Nasion-occipital length	—	190
Basion-nasion length	110	110
Basion-bregma height	144	138[e]
Maximum cranial breadth	140	139
Maximum frontal breadth	—	108
Minimum frontal breadth	97	97
Bizygomatic breadth[c]	135	135
Biauricular breadth	126	126
Basion-prosthion length	—	110
Nasion-prosthion	75	75
Nasal height	55	55
Nasal breadth	28[d]	26
Bijugal breadth	—	122
External palatal breadth	65	66
External palatal length	59	58
Mastoid height	—	34
Mastoid breadth	—	10
Orbital height	37	37
Orbital breadth	41	45[f]
Interorbital breadth	—	18
Nasion-dacryon subtense	—	8.9
Simotic chord	—	7.5
Simotic subtense	—	4.2
Bimaxillary breadth	—	102[g]
Zygomaxillary subtense	—	28[g]
Bifrontal Breadth	—	104
Nasiofrontal subtense	—	16
Biorbital breadth	—	104
Dacryon subtense	—	12[g](r)
Inferior malar length	—	32[g](r)
Maximum malar length	—	56[g](r)
Malar subtense	—	13[g](r)
Minimum cheek height	—	23
Supraorbital projection	—	8
Glabella projection	—	3
Frontal chord	—	112
Frontal subtense	—	17
Frontal fraction	—	50
Parietal chord	—	112
Parietal subtense	—	21
Parietal fraction	—	58
Occipital chord	—	107
Occipital subtense	—	26
Occipital fraction	—	43
Foramen Magnum Length	—	42
Nasion radius	—	103
Subspinale radius	—	111
Prosthion radius	—	115
Dacryon radius	—	94
Zytoorbital radius	—	93[g]
Frontomalar radius	—	86
Ectoconchion radius	—	81
Zygomaxillary radius	—	84g
M1 Alveolar radius	—	90
Bragma radius	—	122
Vertex radius	—	126
Lambda radius	—	113
Opisthion radius	—	46
Basion radius	—	18
Mastoid radius	—	33
Symphysis height	38	38
Body height at foramen	—	34
Body breadth at foramen	—	11
Bigonial breadth	—	114
Bicondylar breadth	—	122
Minimum ramus breadth	36	36
Maximum ramus breadth	—	48
Maximum ramus height	—	63
Mandibular length	—	80
Mandibular angle	—	124
Mandibular ht. distal M2[h]	—	27

[a] After Bass 1987; all measures are from the left unless otherwise indicated by (r).
[b] After Howells 1973; all measures are from the left unless otherwise indicated by (r).
[c] Right side plus 2 mm, doubled.
[d] Low confidence, scaled photographs show cast measurement is correct.
[e] Position of foramen magnum raised superiorly in cast due to molding process, should affect only this dimension.
[f] Disparity due to differences in measurement protocols.
[g] Points estimated because of suture obliteration.
[h] New measurement, height of the mandibular body at the alveolus immediately distal to M2.

General Description

The skeleton was recovered in approximately 350 fragments (inventory by D. W. Owsley, October 1998), representing at least 143 elements (Figure 9). Included originally were the nearly-complete cranium and mandible, all but two teeth (third molars) all complete cervical vertebrae, all thoracic and lumbar vertebrae (complete or fragmentary), parts of the sacrum, fragments of the manubrium, numerous fragments of 22 ribs, portions of both scapulae, complete humeri, complete right and nearly-complete left radii and ulnae, the majority of both os coxae, complete femora, tibiae, and fibulae, and parts of all hands and feet. All major bones were present in multiple fragments.

The skull is dolicocranic (index of 73.9), with a markedly sloping forehead that rises to a vertex far

Table 4. Kennewick Skeleton Postcranial Measurements[a]

	Measurement (in mm)	
	Left	Right
Clavicle		
Maximum length	—[e]	152
Humerus		
Maximum length	341	344
Epicondylar breadth[b]	66	66
Vertical diameter of head	46	47
Maximum diameter at midshaft	23	25
Minimum diameter at midshaft	15	19
Circumference at midshaft	65	73
Minimum circumference	63	71
Radius		
Maximum length	262	—
Ulna		
Maximum length	—	288
Physiological length	—	252
Least circumference	41	43
Os Coxae		
Maximum height	—	215
Maximum breadth	—	167
Femur		
Maximum length	470	471
Bicondylar length	not taken	466
Epicondylar breadth[b]	86[f]	89
Maximum diameter of head	49	49
Anterior-posterior midshaft diameter	36	34
Medial-lateral midshaft diameter	29	27
Anterior-posterior subtrochanteric diameter	28	29
Medial-lateral subtrochanteric diameter	35	34
Midshaft circumference[c]	not taken	92
Torsion indicator[d]	14	14
Tibia		
Length	400	401
Max. diameter at nutrient foramen	41	40
Min. diameter at nutrient foramen	25	24
Circumference at nutrient foramen	103	101
Proximal epiphyseal breadth[b]	82	—
Fibula		
Maximum length	387	386

[a] Measurements taken following Bass (1987), except as noted.
[b] Following Buikstra and Ubelaker (1994).
[c] Taken from CT scanned cross-section.
[d] Following Stewart (1962).
[e] Indicates measurement could not be taken from element.
[f] Medial condyle shows compression from an adjacent object.

posterior to bregma (Figure 10). The vault is high and generally round in both coronal and sagittal views, with a narrow, slightly ridged frontal and no occipital protruberance. The parietals have prominent bosses, beneath which the vault is flat-sided to slightly concave. Temporal lines are remarkably long and rise high on the vault, extending nearly to the lambdoid suture in the posterior and to within 40 mm of the sagittal suture at bregma. Mastoid processes are large but thin and triangular, with deep digastric grooves. Nuchal lines are not particularly rugose.

The face is long, especially when the mandible is included, and relatively narrow. Prominent superciliary arches and unusually thin supraorbital margins border high, rounded, horizontally-oriented orbits. Zygomatics are moderate in size and lack pronounced tubercles, inferior projection, and infraorbital fossae. Canine roots are long and posteriorly curving, resulting in prominent ridges and deep canine fossae. The most striking feature of the face is the broad, projecting nose, which dominates the mid-face. The nasion-opisthion length is equal to or slightly longer than the glabella-opisthion length, giving the sense that the nose is an extension of the forehead slope. The subnasal spine is long and supported by a narrow buttress that begins just superior to prosthion. Lateral margins of the piriform aperture project anteriorly along their entire length.

The postcranial skeleton is that of a tall (for an early hunter-gatherer), moderately muscled individual. The legs are long, with relatively unbowed femora exhibiting low torsion (Table 4, Stewart 1962) and a high platymeric index (85 right, 80 left). A strong asymmetry is evident in the humeri, which have robusticity indices (calculated in the manner of Bass 1987) of 20.6 for the right and 18.5 for the left. Small head diameters indicate that both humeri are rather gracile for the man's size and sex. Distal limb segments are long in proportion to the proximal in both upper and lower extremities, with a radiohumeral index of 76 and a crural (tibia/fibula) index of 86.

Dentition

All permanent teeth were found with the exception of the maxillary right and mandibular left third molars, which appear to have been lost postmortem. Dental attrition is extensive on all teeth except the third molars, exposing secondary dentin on all but the left maxillary second and third molars, and the right third molar. However, in no case was an open pulp cavity breached. Wear in anterior teeth is scored following Smith (1984), as follows, superscript indicating maxillary teeth and subscript indicating mandibulars: $I^{1 \text{ and } 2}$, 7; C^1, 6; $P^{1 \text{ and } 2}$, 8; $I_{1 \text{ and } 2}$, 8; C_1, 6; $P_{1 \text{ and } 2}$, 6. Molars are scored following Scott (1979): M^1, 40; M^2, 38; M^3 12; M_1 36; M_2, 28; M_3 12. Third molars are markedly less worn than the

Table 5. Nonmetric Cranial and Dental Traits of the Kennewick Skeleton[a].

	Left	Central	Right
Cranial			
Metopic Suture	—	absent	—
Supraorbital notch	+, less than half occluded	—	+, less than half occluded
Supraorbital foramen	absent	—	absent
Infraorbital suture	complete	—	—[b]
Mult. infraorbital f.	absent	—	absent
Zygomatico-facial f.	one lg. plus smaller for.	—	one lg. plus smaller for.
Parietal foramen	none	—	none
Sutural bones	(not scored due to obliteration of sutures but appear absent)	—	—
Inka bone	—	absent	—
Condylar canal	patent	—	patent
Hypoglossal canal	divided, inner surface	—	divided, inner surface
Super. sagittal sulcus	—	not accessible	—
Foramen ovale	complete	—	complete
Foramen spinosum	complete	—	no definition of foramen
Pterygo-spinous br.	partial[c]	—	absent
Pterygo-alar bridge	partial[c]	—	partial
Tympanic dehiscence	absent	—	absent
Auditory exostosis	near complete occlusion	—	near complete occlusion
Mastoid foramen	one, on temporal	—	one, on temporal
Mental foramina	one	—	one
Mandibular torus	absent	—	absent
Palatine torus	absent	—	absent
Mylohyoid bridge	complete, center of groove	—	partial, center of groove
Dental[d]		—	
Upper incisor orient.	not winged	—	not winged
Upper first premolar	two roots	—	two roots
Enamel extensions	not scored[e]	—	1 mm, buccal 2nd molar
Roots, lower M1	2	—	2
Roots, lower M2	2	—	2
Third molars[f]	present, not reduced	—	present, not reduced

[a] Taken from the original skull, cast, and photographs, following Buikstra and Ubelacker (1994).
[b] Trait could not be scored.
[c] Assessment uncertain due to damage, bridge might have been complete.
[d] Only the traits that could be scored are shown.
[e] Cast appears to show straight enamel border, but no photo to corroborate.
[f] Upper left and lower right are present, but alveoli indicate original presence of missing teeth.

other teeth, but interproximal wear between the third and second molars has advanced enough (.7 to 1.0 mm) to indicate that the third molars had been in occlusion for some time.

The angles of wear are patterned and bilaterally symmetrical on the upper dentition and nearly symmetrical on lower dentition. In the maxilla, the incisors and canines have horizontal wear labially and slightly superiorly beveled wear lingually. Premolars are rounded bucco-lingually and beveled more markedly lingually. Both first molars are markedly beveled lingually and the right also has slight buccal rounding. Both have rotated lingually on the mesiodistal axis, exposing the buccal roots. The maxillary second molars have complex wear: lingually beveled mesially and concave distally. Mandibular wear is horizontal, except for a slight labial/buccal bevel to the canines and left first premolar. This bevel is noticeably greater on the left side, where the canine and first premolar are worn up to 1 mm below the level of adjacent teeth, evidence the man habitually held objects in the left corner of his mouth. Incisors and the right first premolar show rounded wear, which may indicate that the teeth were used as tools (Brace 1975; Hinton 1981). This is much more pronounced lingually in the central incisors, on which the wear extends 2.5 mm down the lingual side of the root. Antemortem damage is evident only in the left mandibular second premolar, which is cracked and chipped, with rounding of the broken edges.

Figure 9. The skeleton of "Kennewick Man" in approximate anatomical position. Small fragments of ribs, os coxæ, and other larger trabecular bones are not shown. Note the presence of both complete femora; the proximal 2/3 of the right and distal 2/3 of the left are now missing. Right and left radii have been reversed digitally from their original positions in this photograph.

Sex

This individual was male, as indicated by the morphology of the os coxae and skull, metrics of the femur and humerus, and general robusticity of the skeleton. In the os coxae, the greater sciatic notch is narrow. The bodies of the pubic bones are well preserved, exhibiting no ventral arc, but the ischiopubic rami are not sufficiently intact for the subpubic outline or the ischiopubic ridge to be observed. Observable features are characteristically male. The skull is characterized by moderate nuchal development, a large, though narrow, mastoid process, a prominent supra-orbital ridge, and square (if narrow) chin. The supraorbital margin is unusually sharp for a male, however and there is a shallow, narrow preauricular sulcus in the ischium. Both of these traits are more common in females, but overall morphology is strongly male.

Figure 10. The Kennewick skull viewed in right profile.

Muscle attachment rugosities on the postcranial skeleton, while not extreme, are well developed. Although we lack a representative sample of the population from which this skeleton came, the overall size and observed degree of robusticity would be interpreted as male in all modern populations.

Age

The complete union of all epiphyses, including the basilar suture, and the eruption and occlusion of all teeth clearly establish this male as a mature adult. Beyond that, the evidence is somewhat ambiguous, but death probably occurred between 35 and 45 years of age. Data were obtainable from the pubic symphysis, auricular surface, sternal end of the fourth (or fifth) rib, and the degree of ectocranial suture closure. Dental wear, x-ray evidence for incipient osteoporosis, osteoarthritis, and ligament ossification were used as secondary indicators.

Both halves of the pubic symphysis are intact in the Kennewick skeleton and show similar development. The symphyseal face is generally fine-grained, but some remnants of the ridge and furrow system persist. The dorsal plateau is fully developed and there is a distinct rim exhibiting a moderate degree of lipping. The ventral rampart is complete except for a portion of its superior aspect. The pubic tubercle is not yet fully separated from the symphyseal face and no ligament ossifications are evident on the smooth, compact ventral surface. These characteristics correspond to Suchey-Brooks Phase 4 (35+11.5

years: Brooks and Suchey 1990) and Todd's (1921) Phase 6 or 7 (30–39 years).

The auricular surface was somewhat obscured by concretions, but it is sufficiently exposed for the following observations. The surface is coarsely granular with some indications of incipient bone densification. Faint striae remain on the ventral demiface, but transverse organization has all but disappeared. The ventral demiface is marked by numerous micropores and a few macropores. Apical activity is slight to moderate, represented by a dense bony ridge and general surface irregularity. There is some retroauricular activity, but concretions interfere with observation in this area. This pattern most closely compares with Meindl and Lovejoy's Phase 5, with an approximate age of 40–44 years (Bedford et al. 1989 reprinted in Buikstra and Ubelacker 1994; Lovejoy et al 1985; Meindl and Lovejoy 1989), although different perceptions of transverse organization and densification could place it in Phase 4 (35–39 years).

The sternal ends of five ribs were recovered, including one that is assignable with confidence to the fourth or fifth position. Therefore, it is not inappropriate to apply the criteria of Iscan et al. (1984) for estimating age from changes in the sternal end of the fourth rib. In the Kennewick skeleton the sternal rim of this rib has lost the scalloped appearance of young adulthood and is losing some of its regularity. The central arc is still well defined, however, and lacks bony projections. The pit is compact and flared. This gives a composite score of 9, or 33.7–46.3 years (Iscan et al. 1984).

Cranial suture closure is much more advanced than would be expected from the foregoing estimates. Ectocranial and maxillary sutures were observable, but endocranial sutures were obscured by cemented soil. The ectocranial sutures are nearly all fused and obliterated; only the mid-lambdoid and superior sphenotemporal remain fused but not obliterated. This gives composite scores of 20 for the vault and 14 for the lateral-anterior sites or approximate ages of 39–64 and 47–65 years, respectively (Meindl and Lovejoy 1985). Closure of the palatine sutures is also advanced. The incisive, transverse median palatine, and posterior median palatine sutures are fused and mostly obliterated; the anterior median palatine remains partially open. This pattern characterizes middle adulthood (Mann et al. 1987).

Incipient osteoporosis suggests that the Kennewick individual was probably at the older end of the age ranges determined from the os coxae and ribs and closer to the ages indicated by cranial sutures. Beginnings of trabecular densification may be indicated by the roughened appearance of the intertemporal surface of the parietal bones. Such a change may represent partial collapse of the diploe as trabeculae become fewer and more widely spaced (D.G. Steele, personal communication 1996). It may be a less advanced expression of the bilateral thinning of the parietals reported by Ortner and Putschar (1981:290). The right proximal femur, although somewhat obscured by an in-filling of calcite cement, appears to show densification comparable to Walker and Lovejoy's (1985) Phase 5, 40–44 years. The left distal femur (right is too cemented to be readable) appears to have lost some trabecular bone in the distal medullary cavity as indicated by an irregular, cloudy mass of cement in the proximal portion of the metaphysis, where fine trabecular structure would occur in a younger individual.

Two lines of evidence point to the lower end of the age ranges indicated by pelvic, rib and sutural observations. Osteoarthritic attrition, although widespread, is in most cases minor (see *Pathology*) and the wear on the third molars is unusually light relative to the wear on other teeth, although interproximal wear between the second and third molars indicates the third had long been in occlusion. Both of these are behaviorally mitigated, however, and are therefore not reliable age indicators in themselves.

Biological Affiliation

The Kennewick skeleton differs markedly from modern American Indians, particularly those of the Northwestern U.S. Anthroposcopy, craniofacial morphometrics, and discrete dental traits were used to determine to which modern geographic group he was most similar. A fourth method, extraction of ancient mitochondrial DNA was begun by Frederika Kaestle but has not been completed.

When this out-of context, disarticulated skeleton was discovered, I worked from the assumption one must always use in a forensic situation: that the remains were of recent origin and could therefore be identified to one of the common modern populations in eastern Washington. I proceeded to do this following Gill (1984, 1995), Bass (1987), and Stewart (1962). Even though human populations show a wide range of variability in size and shape, and overlap in their ranges of variability both metrically (e.g. Howells 1973) and in the expression of discrete traits, they do exhibit central tendencies that are useful for forensic identification. These facts in mind, I found that the Kennewick remains differed from late prehistoric American Indians of the Pacific Northwest in the direction of the recent European immigrants (Chatters 1997). Northwest native peoples tend from my observations to be brachycranic to mesocranic, with very broad, flaring, anteriorly-placed zygomatics, and slight prognathism. Orbits of the males are markedly rectangular and laterally drooping. Their palates are short, broad, and elliptical, with third molars set medialy relative to the seconds. Mandibles are robust, with near-90° gonial angles and broad, short rami. Chins are broad but blunt and lack bilaterality. Culturally determined characteristics are marked occipital or lambdoidal flattening from cradle board use and rapid dental attrition. With his dolicocrany, projecting face, round, horizontally oriented orbits, distinct, diverging plate, bilateral chin, and gracile mandible with its reclining, narrow ramus, the Kennewick skeleton differed in almost every respect from this pattern. He also lacked cradle boarding and had unusually light dental wear for his age. While any one Amerind skull might exhibit one or more of these characteristics, I have yet to see one that exhibits all or even most of them.

Other characteristics that can be used to distinguish among modern regional populations have been femoral shape (Gill 1984; Stewart 1979) and body dimensions. Femoral shafts of late prehistoric Native peoples tend to be distinctly curved in the anterioposterior axis, with high torsion and platymeria (e.g., Cybulski et al. 1981:53). The people also are short statured. For example, mean stature of males from Prince Rupert Harbor was only 162.8 ± 3.8 cm (Cybulski et al. 1981:53) and a group of 22 Late Archaic males from the Dalles region of the Columbia was estimated at only 163.3 ± 1.8 cm (research notes of the author). The Kennewick skeleton is significantly taller, with platymeria, and low femoral curvature and torsion. While these features distinguish him from local Amerind populations, the extent to which they are under genetic influence is poorly known. Certainly, we know that body size is strongly influenced by health and nutrition and that femoral shape responds to mechanical stresses, both of which are to some degree under cultural control.

Cranial characteristics, femoral morphology and stature together led me, in the forensic venue, to suggest an affiliation with modern Euroamericans. Once the skeleton's age was known, however, I referred to the remains as "Caucasoid-like" (Preston 1997).[5] I did not state, nor did I intend to imply, once the skeleton's age became known, that he was a member of some European group (Chatters 1998).

Forensic trait lists are intended to facilitate identification and have been developed only to distinguish among the most numerous or frequently encountered *modern* groups: east Asians, Amerinds, west Africans (African Americans), and western Eurasians. The overlap that develops when we move between these most populous demes or into the past makes affiliation of individuals by discrete traits problematic at best; at some point in the past we are approaching a common ancestral morphology. Ideally, if we are hoping to identify places and populations of post-diaspora origin, we should compare ancient people with their contemporaries and predecessors in various parts of the world, not with their successors. However, given the dearth of skeletons predating the Kennewick specimen in eastern Asia, (the probable most recent place of geographic origin for his ancestors) this is not currently possible except in the most limited way (e.g., Neves and Puchiarelli 1991; Steele and Powell 1994). It is possible, however, to compare the specimen with modern groups in search of the population with the closest statistical similarity and thus a possible common ancestry.

This can be done using the craniofacial morphometry of Howells (1973, 1989) (e.g., Jantz and Owsley 1997, 1998; Neves and Pucciarelli 1989; Steele and Powell 1992, 1994). Applying this approach, Chatters et al. (1999) used principal components analysis to compare craniometrics of the Kennewick skull cast (Table 3) with the Ainu and the 18 modern populations that Howells (1989) believes comprise most of the metric variability of modern *Homo sapiens*. A graphic comparison of the first two components, which included size (Figure 11), placed him nearest the Pacific Islanders and Ainu—Brace and Hunt's (1990) Jomon-Pacific cluster. When size was factored out, he was an extreme outlier, with no close relationship to any modern population. Powell and Rose (1999) reached the same conclusion using a wider array of techniques and a variety of human databases. These results are consistent with previous analyses, which find that the

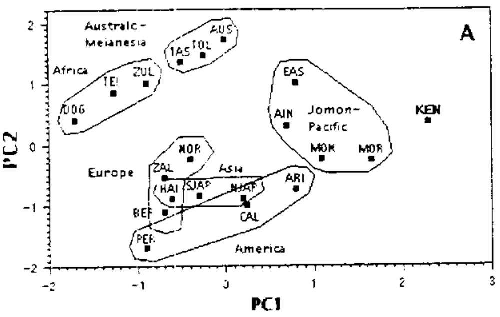

Figure 11. A plot of the first two principal components in a comparison with 19 populations in the Howells database. This comparison considers both size and shape, and the Kennewick skull (KEN) clusters outside modern populations, but near the Jomon-Pacific Cluster (EAS-Easter Island, MOR-Moriori, MOK-Mokapu, and AIN-Ainu.) Other populations are as follows: Asian (NJAP-North Japan, SJAP-South Japan, HAI-Hainan Chinese.) European (NOR-Old Norse, BER-Berg, ZAL-Zalavar), African (ZUL-Zulu, DOG-Dogon, TEI-Tieta), Australomelanesian (AUS-Australian, TAS-Tasmanian, TOL-Tolai), and American (ARI-Arikara, PER-Peru, CAL-Santa Cruz). From Chatters et al. 1999: Fig. 1a.

closest craniofacial morphometric affinity of northern Paleoamericans is generally to the Pacific Islanders and South Asians (Steele and Powell 1992, 1994), and that when size is factored out, they are often far removed from modern peoples (Jantz and Owsley 1998). In general appearance, the Kennewick skull does somewhat resemble Polynesians, particularly Easter Islanders, and Jomon/Ainu.

Dental discrete traits (Table 5) echo this Jomon-Pacific affinity. Turner (1985, 1990) has identified two Asian dental patterns, the Sinodont, which characterizes modern north Asians and Amerinds, and the Sundadont, which he believes to be an earlier pattern retained in south Asian and Pacific Island groups. Differences are seen in root numbers and crown characteristics of molariform teeth, and winging and shoveling of incisors. The Sinodont pattern includes high frequencies of shoveled and double-shoveled incisors; winged upper central incisors; three-rooted lower first molars; single-rooted upper first premolars and lower second molars; reduced, pegged, or congenitally absent third molars; single lingual cusps on lower first premolars; and five-cusped lower first and second molars. Sundadonts tend to exhibit weak shoveling, two-rooted upper first premolars and lower first and second molars, two lingual cusps on the lower first premolar, and six cusps on the lower first molar and four on the lower second, and lack incisor winging. Cusp patterns and shoveling cannot be observed on the Kennewick teeth, but the remaining characteristics are those common to the Sundadont pattern (see also Powell and Rose 1999). Thus, craniofacial and dental evidence converge to suggest an affinity—a common origin—with some modern coastal and maritime peoples of east Asia and the Pacific.

Stature and Body Mass

Stature is estimated from the length of the femur, as recommended by Waldron (1998) and body mass from the diameter of the femoral head. Stature estimation is dependent at the outset on the population from which an individual is derived, leaving a dilemma in this case. This skeleton is old enough to predate the modern populations on which stature formulae are based, and his physical characteristics distinguish him from Mongoloids in general and Amerinds specifically. Thus I had the dilemma of deciding which formula or formulae to use. My solution is to use the crural index to identify the modern populations with the most similar lower limb proportions, then choose from among those the one most proximal to the discovery site. The Kennewick skeleton's crural index of 85.1 places him closest to African Americans, Arizona Amerinds, Melanesians, Egyptians, and Pygmies (Ruff 1994; Trinkaus 1981). Stature equations are available for African Americans and Mesoamericans, who are geographically close to Arizona Amerinds. Because of proximity and the great genetic distances between Africans and all other world populations (Cavalli-Sforza et al. 1994) the appropriate equations are Mesoamerican. Averaging estimates derived from Trotter and Gleser's (1958) and Genoves' (1967) equations gives a stature of 173.1 ± 3.4 cm.

I calculated body mass from the diameter of the femoral head using the three equations of Ruff et al. (1997:175). The Kennewick man's femoral head diameter of 49 mm gave estimates of 69.8 (Equation 1), 74.6 (Equation 2), and 71.5 kg (Equation 3), or about 70-75 kg. The ratio of stature to mass indicates a man of moderate robusticity.

General Health and Nutrition

Strong, intact teeth, thick cortical bone in the limbs, and large size indicate an individual who was generally well fed, perhaps in part due to the anadromous fish diet suggested by the carbon isotope ratio of -14.9 per mil (Taylor et al. 1998). X-ray of the distal femora, although partially obscured by mineral

Table 6. Pathologies and Traumas of the Kennewick Skeleton.[a]

Defect	Diagnosis	Time of Injury/Illness
Healed chip from radial head	Radial head fracture	Adolescence
Extensive remodeling in humeral septum, olecranon fossa	Hyperextension or inflammation associated with radial head fracture	Adolescence
Left humerus 10% smaller than right and exhibiting much reduced musculoskeletal markings	Crippling due to elbow injury?	Adolescent onset, lifelong debility
Callused depression in left frontal	Healed depressed fracture	Antemortem, adolescence or adulthood
Healed bilateral anterior fracture of ribs 3-6 with pseudoarthrosis in 3 to 4 ribs	Flail chest caused by blunt trauma to upper mid-chest	Antemortem, adulthood
Healed projectile wound in right ilium, with signs of active sinus and cloaca for drainage	Chronic osteomyelitis in inflicted wound from which foreign object was never removed	Antemortem
Chip off posterior right glenoid fossa, no remodeling	Possible posterior dislocation of shoulder, but may be result of postmortem manipulation of stiffened corpse	Peri-mortem
Minor to moderate lipping and pitting of upper neck, upper thoracic vertebrae, shoulders, elbows and knees	Osteoarthritis	
Exostoses nearly filling both external auditory meati	Bony reaction to prolonged or frequent exposure to cold water or air	Antemortem
Lysis and sclerosis of outer table of greater wing, left sphenoid. Area of lysis has platy appearance; sclerosis is in woven bone stage	Acute, osteomyelitis from infection originating in adjacent soft tissue	Ante/peri-mortem

[a] For details see Chatters (2000).

cement in the medullary cavities, failed to show any Harris lines. At this man's age, however, we would expect trabecular remodeling to have obliterated most or all such anomalies. The advanced state of dental wear obscures enamel hypoplasias in all but the second and third molars. A single linear enamel hypoplasia is visible on the left mandibular second molar, 2.8 mm from the cemento-enamel junction (CEJ). This is approximately 50 percent of crown height. The crowns of second molars begin developing in males at a mean of 3.7 to 3.8 years and are complete at a mean of 6.5 to 6.7 years (Hillson 1996, Table 5.1). This would place the hypoplasia at approximately 5 to 5.5 years. In their analysis, Powell and Rose (1999) detected a second hypoplasia near the CEJ of the right mandibular canine at 1.66 mm, also suggesting an age of 5–5.5 years for the defect; they place the molar hypoplasia at 2.26 mm from the CEJ, and estimate its occurrence at 6–6.5 years of age.

Pathology

Evidence of good nutrition contrasts with an unusually high number of injuries and bacterial infections, which I only summarize here (Table 6). For a detailed discussion of pathologies, see Chatters (2000).[6]

Attritional pathologies are represented by osteoarthritis, periodontal disease, and incipient dental abscesses. Osteoarthritis is extensive but nowhere severe. Lesions are seen in the left occipital condyle, atlas, axis, fourth and fifth cervical and uppermost two lumbar vertebrae, glenoid fossae of both scapulae, both elbows, and both knees. Damage is greatest, but still only moderate on the left occipital condyle, which is eburnated, the right shoulder and elbow, and the posterior surface of the lateral condyle of the left femur. There is no evidence of caries in Kennewick Man's teeth, but minor periodontal disease was widespread and small incipient abscesses are evident in X-rays at the apices of several molars.

Traumatic injuries are extensive and some were accompanied by infection. The man suffered a fracture of the left radial head and apparently-associated damage to the left distal humerus, probably in adolescence, a minor depressed fracture to outer table of the left frontal bone, massive trauma to the anterior chest, and a projectile wound in the right ilium which developed chronic osteomyelitis. All of these injuries had healed. Unhealed pathologies are acute osteomyelitis of the greater wing of the left sphenoid and perimortem chipping of the posterior edge of the glenoid of the right scapula. There also is severe auditory exostosis in both ears, to the extent that the external meati are almost closed.

The major wounds were debilitating to greater or lesser degree. The elbow injury appears to have diminished the man's use of the left arm, which is markedly less developed both in bone cross-section and musculoskeletal markings (robusticity difference of 10 percent). The chest wound, if a single event, entailed at least seven fractures of at least six ribs on both sides of the sternum. Fractured ends of least three and possibly four ribs, two right and one or two left, failed to heal together, forming pseudoarthroses. This indicates the man suffered a condition known as flail chest, in which a segment of chest wall moves independently and counter to the chest wall as a whole (Beeson and Saegester 1983). It reduces breathing efficiency and coughing effectiveness (Kirsch and Sloan 1977), and would have affected his capability for strenuous exercise, at least until his body adapted.

The most interesting and informative trauma is the projectile wound (Figures 6,7,8). The large, impact fractured blade of an atlatl dart entered into or just anterior to the iliac crest from approximately 45 ± 10° superior to the transverse plane and 30 ± 10° anterior to the coronal plane,[7] becoming completely enclosed between the dorsal and ventral layers of cortical bone. The bone around the embedded stone point shows extensive lysis and remodeling, indicating an initial, acute infection, followed by a period of healing. A gap between the bone and stone that is walled by new cortical bone, discrete pockets within this space, and a drainage channel from the space to the iliac crest show that the infection was eventually isolated from the body by scar tissue and bone callus, but persisted and drained pus from the man's hip throughout his life. The condition is chronic osteomyelitis, which rarely heals spontaneously in the absence of aggressive medical treatment (Mann and Murphy 1990; Waldvogel et al. 1971). The wound affects part of the origin of the iliacus muscle, which flexes the thigh (Warfel 1974), and would probably have caused some discomfort when the man walked.

Acute osteomyelitis is evident on the greater wing of the left sphenoid and appears to have been active at the time of death (Chatters 2000:Figure 8). The cause for this infection is not immediately apparent, but soft tissue infection in the pharynx or associated with a penetrating wound at the right temple are possibilities.

There is also an indication of perimortem injury to the right scapula, where a small chip has been driven off the posterior edge of the glenoid fossa. Discoloration identical to that of the scapula as a whole and lack of evidence for healing indicate that the damage occurred perimortem. This sort of injury can occur with posterior dislocation of the right shoulder (Rowe 1988), but could conceivably have occurred with postmortem manipulation of the stiffened corpse.

The severe auditory exostoses are informative about the man's behavior and environment. Kennedy (1986) has shown that auditory exostoses are often caused by contact with cold air or water. Soft tissues in the posterior aspect of the auditory canal are very thin, making the adjacent periosteum subject to cold-trauma. The injured periosteum responds by producing reactive bone, which thickens into auditory exostoses. Evidently, the Kennewick man spent a good deal of time in cold water of the Columbia River or endured harsher winters than the area now experiences.

Manner of Death

At least three of the pathological conditions could have been associated with this man's death, although it is not possible to pinpoint a manner of death with any certainty. Chronic osteomyelitis around the projectile point, acute osteomyelitis, and perimortem injury could all have contributed. Chronic osteomyelitis, like that in the projectile point wound,

Table 7. Comparison of the Kennewick Skeleton with Other Paleoamerican Males based on Metric Indices, Stature, and Age.

Measure	Browns Valley[d]	Horn Shelter	Hourglass Cave	Spirit Cave[d]	Wizards Beach[d]	Gore Creek	Mean	Kennewick
Cranial index	71.0[e]	73.8	—	70.2	72.8	—	71.9 ± 1.6	73.5
Orbital index	83.0	78.0	—	78.6	85.3	—	81.2 ± 3.5	80.4
Upper face index	46.4	51.2	—	47.8	54.7	—	50.2 ± 3.8	55.6
Nasal index	48.0	55.0	—	52.1	47.3	—	50.5 ± 3.5	47.3
Palatal index	81.2	90.6	—	86.2	83.9	—	85.5 ± 4.0	84.8
Height index[b]	91.4	93.8	—	91.8	91.3	—	92.3 ± 1.1	90.5
Facial forwardness[c]	2.88	2.79	—	2.73	2.82	—	2.80 ± 0.06	3.06[a]
Crural index	—	85.1	—	81.6	84.7	83.6	83.8 ± 1.5	85.1
Platymeric index	75.0	68.8	—	81.2	77.1	66.0	73.6 ± 6.2	82.5
Platycnemic index	—	52.6	—	65.7	59.0	57.5	58.7 ± 5.4	61.0
Humeral robusticity	—	18.9	—	17.4	18.9	—	18.4 ± 0.9	18.5[o]
Femoral robusticity	12.1	12.5	—	12.4	13.3	13.3	12.7 ± 0.5	13.5
Stature (all ± 4) cm	165.1[f]	165.4	161.6[i]	164.2	171.8	166.5[m]	165.8 ± 3.4	173.1[a]
Age	25-35[g]	35-44[h]	35-45[j]	40-44[k]	32-42[l]	27-35[n]	—	35-45

[a] Significantly different values.

[b] Calculated as bregma radius/size factor (geometric mean of cranial length, max. breadth, bregma radius, nasion radius, and prosthion radius).

[c] Sum of nasion radius, subspinale radius, prosthion radius, zygomaxillary radius/size factor.

[d] Postcranial values by David R. Hunt, used courtesy of Richard L Jantz; Browns Valley skull measurements from Owsley and Jantz 1999:89.

[e] Values by David Hunt, used courtesy of Richard L. Jantz., based on original skull; no confidence in cast reconstruction of length and breadth.

[f] Based on partial femur length after Steele and Bramblett 1988, using the formula for segments 1 and 2.

[g] Barbara O'Connell, personal communication 1999.

[h] Young 1988.

[i] Value reported by Mosch and Watson 1996 is 162.5 cm, although they do not specify the formula used. I presume it to be the Mongoloid equation of Trotter and Gleser 1958, back computed for femur length, and recalculated stature using Mesoamerican formulae as described in the text.

[j] Mosch and Watson 1996.

[k] Jantz and Owsley 1997.

[l] Edgar 1997.

[m] Value reported by Cybulski et al. 1981 is 168 cm, based on Mongoloid formula of Trotter and Gleser (1958).

[n] Cybulski et al. 1981.

[o] Robusticity indices of right humeri for Kennewick and Horn Shelter are both 20.6.

typically persists for years without risk to the victim. Before antibiotics, however, nearly 10 percent of sufferers developed secondary septicemia, sometimes years after the initial infection, through spread of bacteria in the blood stream (Wilensky 1934). Acute osteomyelitis in the left sphenoid is evidence of an active infection in soft tissue, also implicating septicemia. Finally, soft tissue trauma associated with the accident that injured the shoulder (if sustained before death), would be the bodily insult most proximal to the man's demise.

Comparison with Other Paleoamericans

The Kennewick skeleton differs significantly from modern Amerinds, but he shares many features with other Paleoamerican males, when they are treated as a single population.[8] Six males with radiocarbon dates older than 8000 B.P. are complete enough for comparison in one or more respects with the Kennewick skeleton. These are the specimens from Brown's Valley, Minnesota (Jenks 1937), Horn Shelter, Texas (Young 1988), Hourglass Cave, Colorado (Mosch and Watson 1996), Spirit Cave and Wizard Beach, Nevada (Edgar 1997; Jantz and Owsley 1997), and Gore Creek, British Columbia (Cybulski et al. 1981). Table 7 compares these individuals according to cranial and postcranial indices, estimated stature, and age. Metric data, unless otherwise cited, have been collected by me from the original bones (Wizard Beach, Horn Shelter), a stereolithograph based on original radiometric data (Spirit Cave), or cited literature. Data are arranged longitudinally from east (Brown's Valley) to west (Gore Creek). Cranial, upper facial, nasal, orbital, crural, femoral and humeral robusticity, and platymeric and platycnemic indices are standard ratios (Bass 1987). External palatal index is length/breadth X 100. The height and facial forwardness indices are calculated differently from the rest. Because several skulls lacked the cranial base, I could not compute standard height indices (which require basion-bregma height) for all skulls. Instead, I divided 100 times the bregma radius by the geometric mean of glabellar length, maximum cranial breadth, and the bregma, prosthion, and nasion radii, resulting in a height corrected for overall cranial size. The facial forwardness index is computed as 100 X the sum of the prosthion, subspinale, zygomaxillare, and nasion radii, divided by the geometric mean used in computing the height index. Left elements are used for postcranial indices. Stature is computed in the manner described for the Kennewick skeleton because the crural indices are comparable. Ages are as published.

As a group the Paleoamericans tend to have high, dolicocranic skulls, medium to broad faces, and narrow to medium noses (see Bass 1987). Their faces are placed well forward on the cranium, as noted by Jantz and Owsley (1998). They are platycnemic to hyperplatycnemic and platymeric to varying degrees, and tend to have high crural indices. In the low, forward faces and high crural indices, they appear to retain vestiges of a tropical origin, even long past the original *Homo sapiens* emergence from Africa. Had they come from a fully arctic-adapted parent population, we would expect them to exhibit the longer, straighter face and shorter distal limbs that are common to high latitude populations (e.g., Ruff 1994).

The Kennewick skeleton compares favorably with this group, being significantly different from the other males in only two respects: stature and facial forwardness. He is taller and has an even more anteriorly placed face. His orbital, upper face, and cranial height indices, and his femoral robusticity are outside the group range, but not significantly so. Even in his age at death he is normal. Most Paleoamerican males died between the ages of 32 and 45; only three may have been younger at their deaths.

One interesting characteristic of the Kennewick skeleton is the difference between his humeral and femoral robusticities, when compared with the other males. Although he is the most robust in the femur, he is the second least robust in the left humerus. This may be due to his elbow injury, but even in the right arm he is no more robust than the Horn Shelter male, who has much lower femoral robusticity. Apparently, he had big legs but a rather slight upper body in comparison with his contemporaries.

Kennewick also is comparable to other Paleoamericans in his dissimilarity to modern Amerinds. There is a tendency for early North Americans to resemble South Asians and Pacific Islanders more closely than other modern peoples, but as with Kennewick Man, most individuals are dissimilar to any modern population (Jantz and Owsley 1997, 1998; Steele and Powell 1992, 1994). Exceptions are the Buhl woman (Green et al. 1998), which has been shown through morphometric analysis to have cranial morphometry typical of an Ainu (Lovvorn et al. 1999), and the Wizards Beach male, who is similar to modern Amerinds (but also to Europeans and Polynesians; Jantz and Owsley 1998). Jantz and Owsley (1998), using some of the same skeletons summarized in Table 7, further suggest that there may have been multiple, physically distinct populations in Early-Holocene North America—groups too disparate to be derived from a single, recently-arrived parent population (but see Powell and Neves 1999). Neves and his co-workers (e.g., Neves and Pucciarelli 1989, 1991; Neves et al. 1996, 1998) have found further that the earliest South Americans differ from the North Americans and most closely resemble ancient and modern peoples of Africa and Australo-Melanesia.

These observations are hinting that the early human history of the Western Hemisphere south of Alaska may be more complex than the single Amerind migration model (e.g., Greenberg et al. 1986; West 1996b) can accommodate (Neves et al. 1996). Recent work in linguistics (Nichols 1990), molecular genetics (Schurr 1999), and archaeology (Meltzer 1993, 1997; Sandweiss et al. 1998) are also revealing too much differentiation for a single terminal Pleistocene arrival (Meltzer 1994). The technologies of Clovis and Monte Verde, for example, are much too disparate for either to be derived from the other or to have recently shared a common parent. Realization that the radiocarbon record has temporally compressed the evidence (Fiedel 1999) alleviates some of the pressure, but not all. If the early differentiation is to be reconciled with a terminal Pleistocene arrival, little earlier than 14,000 years ago, then it is mandatory that we acknowledge the possibility of multiple migrations by culturally and physically distinct peoples (Meltzer, e.g., 1994, 1997), some of whom have not persisted to the present day in recognizable form. The fact that early peoples do not resemble modern North Asians, but that many modern North American Indians do, further raises the possibility that post-Pleistocene gene flow and/or migration contributed significantly to the human biology of the Americas (Chatters 1998; Lahr 1997; Steele and Powell 1999).

Summary

The Kennewick skeleton was the remains of a moderately-robust middle aged man who stood approximately 173.1 ± 3.6 cm tall and weighed approximately 70–75 kg. Geochronology, a projectile point of early Cascade style in his hip, and a radiocarbon date of 8410 ± 60 B.P. place his time firmly in the latter part of the Early Holocene. Although apparently well nourished and healthy in his youth, he suffered repeatedly from serious injuries, including a debilitating fracture of the left elbow, a massive thoracic trauma that caused a chronic flail chest, a spear wound in the right ilium that developed a chronic infection, and an acute infection in the left side of his head. The manner of his death cannot be pinpointed, but acute and chronic bone infections point to septicemia, and a possible, final, shoulder-dislocating injury is a strong candidate. The man's dental and craniofacial characteristics show an affinity with Ainu and Pacific Island peoples, but make him stand out from modern American Indians, especially those who occupied Northwestern North America in later prehistory. He does, however, compare favorably with other Paleoamerican males, although he is significantly taller and has a more projecting face. The Kennewick man has offered a unique window into America's past, and with thorough, thoughtful, respectful, replicated study, will add significantly to our understanding of the origins, lives and deaths of America's earliest inhabitants.

Acknowledgments. Many people, professionals, and laymen alike contributed to the research on Kennewick Man. Tom McClelland, Kenneth Ried, Scott Staples, and Scott Turner helped me recover the remains. Kenneth Lagergren, DDS, produced the dental X-rays; Kennewick General Hospital donated X-ray and CT scans of the skeletal material. Jon Southon of Lawrence Livermore National Laboratory provided the AMS run and Alan Busacca analyzed the sediments, both at no cost. This work has benefited from conversations with Jane Buikstra, Amy Dansie, George Gill, Grover Krantz, Marta Lahr, David Meltzer, Walter Neves, Douglas Owsley, Joseph Powell, Christopher Ruff, Gentry Steele, and especially Thomas Stafford. Meltzer, Owsley, Stafford, Steele, and two anonymous reviewers commented on earlier versions of the manuscript and their input is much appreciated. Special thanks to Benton County Coroner Floyd Johnson for giving the opportunity to work with this skeleton and for having the courage to order the radiocarbon dating of the bone. This paper is dedicated to my friend and colleague, the late Catherine McMillan.

References Cited

Ames, K. N., D. E. Dumond, J. R. Galm, and R. Minor
1998 Prehistory of the Southern Plateau. In *Handbook of North American Indians, Vol. 12 Plateau*, edited by D. L. Walker, pp. 29–48. Smithsonian Institution, Washington, D.C.

Atwater, B. S.
1986 Pleistocene Glacial-Lake Deposits of the Sanpoil River Valley, Northeastern Washington. *U. S. Geological Survey Bulletin* 1661. U.S. Government Printing Office, Washington, D.C.

Bacon, C. R.
1983 Eruptive History of Mount Mazama and Crater Lake Caldera, Cascade Range, U.S.A. *Journal of Volcanology and Geothermal Research* 18:57–117.

Baker, V. R., B. N. Bjornstad, A. J. Busacca, K. R. Fecht, E. P. Kiver, U. L. Moody, J. G. Rigby, D. F. Stradling, and A. M. Tallman.
1991 Quaternary Geology of the Columbia Plateau. In *Quaternary Nonglacial Geology: Coterminous United States*, edited by R. B. Morrison, pp. 215–250. Geological Society of America, Boulder.

Bass, W. M.
1987 *Human Osteology: A Laboratory and Field Manual*. 3rd ed. Missouri Archaeological Society, Columbia.

Beeson, A., and F. Saegesser
1983 *Color Atlas of Chest Trauma*. Medical Economics Books, Oradell, NJ.

Bense, J. A.
1972 *The Cascade Phase: A Study in the Effect of the Altithermal on a Cultural System*. Unpublished Ph.D. dissertation, Department of Anthropology, Washington State University, Pullman.

Birdsell, J. B.
1951 The Problem of the Peopling of the Americas as Viewed from Asia. In *The Physical Anthropology of the American Indian*, edited by W. S. Laughlin, pp. 1–68. Edwards Brothers, Ann Arbor.

Bonnichsen, R. and D. G. Steele (editors)
1994 *Method and Theory for Investigating the Peopling of the Americas* Center for The Study of the First Americas, Oregon State University, Corvallis.

Brace, C. L.
1975 Comment on Wallace: Did la Ferrassie I Use His Teeth as a Tool? *Current Anthropology* 16:396–397.

Brace, C. L., and K. D. Hunt
1990 A Nonracial Craniofacial Perspective on Human Variation: A(ustralia) to Z(uni). *American Journal of Physical Anthropology* 82:341–360.

Brooks, S. T., and J. M. Suchey
1990 Skeletal Age Determination based on the Os Pubis: A Comparison of the Ascadi-Nemeskeri and Suchey-Brooks Methods. *Human Evolution* 5:227–238.

Buikstra, J. E., and D. H. Ubelacker
1994 *Standards for Data Collection from Human Skeletal Remains*. Research Series 44 Arkansas Archeological Survey, Fayetteville.

Butler, B. R.
1961 *The Old Cordilleran Culture in the Pacific Northwest*. Occasional Paper No. 5. Idaho State College Museum, Pocatello.

1962 *Contributions to the Prehistory of the Columbia Plateau: A Report on the Palouse and Craig Mountain Sections*. Occasional Paper No. 9. Idaho State College Museum, Pocatello.

Cavalli-Sforza L. , P. Minozzoi, and A. Piazza

1994 *The History and Geography of Human Genes*. Princeton University Press, Princeton.

Chatters, J. C.

1997 Encounter with an Ancestor. *Anthropology Newsletter* 38(1):9,10.

1998 Human Biological History, *Not* Race. *Anthropology Newsletter* 39(2):19, 21.

2000 Repeated, Severe Trauma in a Paleoamerican Skeleton from Kennewick, Washington, U.S.A. Manuscript on file, Applied Paleoscience, Richland, Washington.

Chatters, J. C., and K. A. Hoover

1992 Response of the Columbia River Fluvial System to Holocene Climatic Change. *Quaternary Research* 37:42–59.

Chatters, J. C., W. A. Neves, and M. Blum

1999 The Kennewick Man: A First Multivariate Analysis. *Current Research in the Pleistocene* 16:87–90.

Chatters, J. C., and D. Pokotylo

1998 Prehistory: Introduction. In *Plateau*, edited by D. L. Walker, pp. 73–80. Handbook of North American Indians, vol. 12. Smithsonian Institution, Washington, D.C.

Cleveland, G., B. Cochran, J. Ginnegar, and H. Hammatt

1976 *Archaeological Reconnaissance on the Mid Columbia and Lower Snake River Reservoirs for the Walla Walla District Corps of Engineers*. Project Reports 27. Washington Archaeological Research Center, Washington State University, Pullman, Washington.

Cybulski, J. S., D. E. Howes, J. C. Haggarty, and M. Eldridge

1981 An Early Human Skeleton from South-Central British Columbia: Dating and Bioarchaeological Inference. *Canadian Journal of Archaeology* 5:49–57.

Dillehay, T., and D. J. Meltzer (editors)

1991 *The First Americans, Search and Research*. CRC Press, Boston.

Edgar, H. J. H.

1997 Paleopathology of the Wizards Beach Man and Spirit Cave Mummy. *Nevada State Historical Quarterly* 40:57–61.

Fagan, J.

1999 *Analysis of the Lithic Artifact Embedded in the Columbia Park Remains*. Report submitted to the National Park Service, U.S. Department of the Interior, Washington, D.C.

Fiedel, S. J.

1999 Older Than We Thought: Implications of Corrected Dates for Paleoindians. *American Antiquity* 64:95–116.

Franklin, J. F., and C. T. Dyrness

1988 *Natural Vegetation of Washington and Oregon*. Oregon State University Press, Corvallis.

Fryxell, R., and R. D. Daugherty

1963 *Schematic Geoarchaeological Chronology of Eastern Washington and Related Areas*. Report of Investigations 21. Laboratory of Anthropology, Washington State University, Pullman, Washington.

Galm, J. R., G. D. Hartmann, R. A. Masten, and G. O. Stephenson

1981 *A Cultural Resource Overview of Bonneville Power Administration's Mid- Columbia Project, Central Washington*. Eastern Washington University Reports in Archaeology and History 100–116. Archaeological and Historical Services, Cheney.

Genoves, S. C.

1967 Proportionality of Long Bones and Their Relation to Stature among Mesoamericans. *American Journal of Physical Anthropology supplement* 26:67–78.

Gill, G. W.

1984 A Forensic Test Case for a New Method of Geographical Race Determination. In *Human Identification* , edited by T. Rathbun and J. Buikstra, pp. 329–339. Charles C. Thomas, Springfield.

1995 Challenge on the Frontier: Discerning American Indians from Whites Osteologically. *Journal of Forensic Sciences* 40:783–788.

Gough, S.

1995 *Description and Interpretation of Late Quaternary Sediments in the Rocky Reach of the Columbia River Valley, Douglas County, Washington*. Unpublished Master's thesis, Departments of Geology, Geography, and Anthropology, Eastern Washington University, Cheney.

Green, T. J., B. Cochran, T. W. Fenton,, J. C. Woods, G. L. Titmus, L. Tieszen, M. A. Davis, and S. J. Miller

1998 The Buhl Burial: A Paleoindian Woman from Southern Idaho. *American Antiquity* 63:437–456.

Greenberg, J. H., C. G. Turner, and S. L. Zegura

1986 The Settlement of the Americas: A Comparison of Linguistic, Dental and Genetic Evidence. *Current Anthropology* 27:477–497.

Hammatt, H. H.

1977 *Late Quaternary Stratigraphy and Archaeological Chronology in the Lower Granite Reservoir Area, Lower Snake River, Washington*. Master's thesis, Washington State University, Pullman. University Microfilms, Ann Arbor.

Hartmann, G. D.

1986 *Preliminary Test Excavations at Three Prehistoric Archaeological Sites in Franklin County, Washington*. Eastern Washington University Reports in Archaeology and History, No. 100–56. Archaeological and Historical Services, Cheney, Washington.

Hillson, S.

1996 *Dental Anthropology*. Cambridge University Press. Cambridge.

Hinton, R. J.

1981 Form and Patterning of Anterior Tooth Wear among Aboriginal Human Groups. *American Journal of Physical Anthropology* 54:555–564.

Howells, W. W.

1973 *Cranial Variation in Man; A Study of Multivariate Analysis of Patterns of Difference among Human Populations*. Papers of the Peabody Museum of Archaeology and Ethnology, Vol 67. Harvard University, Cambridge.

1989 *Skull Shapes and the Map. Craniometric Analysis in the Dispersion of Modern Homo*. Papers of the Peabody Museum of Archaeology and Ethnology, Vol 79. Harvard University, Cambridge.

Hrdlicka, A.

1937 Early Man in America: What Have the Bones to Say? In *Early Man as Depicted by the Authorities at the International Symposium at the Academy of Natural Sciences, Philadelphia, March 1937*, edited by G. G. McCurdy, pp. 93–104. Lippincott, London.

Huckleberry, G., T. W. Stafford Jr., and J. C. Chatters

1998 *Preliminary Geoarchaeological Studies at Columbia Park, Kennewick, Washington, USA*. Report submitted to the U.S. Army Corps of Engineers, Walla Walla District.

Huckleberry, G., and J. K. Stein

1999 *Analysis of Sediments Associated with Human Remains Found at Columbia Park, Kennewick, WA*. Report Submitted to the National Park Service, U.S. Department of the Interior, Washington, D.C.

Iscan, M. Y., S. R. Roth, and T. K. Wright

1984 Metamorphosis at the Sternal Rib End: A New Method to Estimate Age at Death in White Males. *American Journal of Physical Anthropology* 65:147–156.

Jackson, P.
1985 Climate. In *Atlas of the Pacific Northwest*, edited by A. J. Kimerling and P. L. Jackson, pp. 48–57. 7th ed. Oregon State University Press, Corvallis.

Jantz, R. L., and D. W. Owsley
1997 Pathology, Taphonomy, and Cranial Morphometrics of the Spirit Cave Mummy. *Nevada State Historical Quarterly* 40:62–84.
1998 How Many Populations of Early Americans Were There? *American Journal of Physical Anthropology* Supplement 26:228.

Jenks, A. E.
1937 *Minnesota's Browns Valley Man and Associated Burial Artifacts*. Memoir No. 49. American Anthropological Association, Menasha, Wisconsin.

Kennedy, G.
1986 The Relationship between Audotory Exostosis and Cold Water: A Latitudinal Analysis. *American Journal of Physical Anthropology* 71:401–415.

Kirsch, M. M., and H. Sloan.
1977 *Blunt Chest Trauma, General Principles of Management*. Little, Brown, Boston.

Lahr, M. M.
1997 History in the Bones. *Evolutionary Anthropology* 6:2–6.

Laughlin, W. S. and A. B. Harper (editors)
1976 *The First Americans: Origins, Affinities, and Adaptations*. Gustav Fischer, New York.

Leonhardy, F. C., and D. G. Rice
1970 A Proposed Culture Typology for the Lower Snake River Region, Southeastern Washington. *Northwest Anthropological Research Notes* 4:1–29.

Lovejoy, C. O., R. S. Meindl, T. R. Pryzbeck, and R. P. Mensforth
1985 Chronological Metamorphosis of the Auricular Surface of the Ilium, A New Method for the Determination of Adult Skeletal Age at Death. *American Journal of Physical Anthropology* 68:15–28.

Lovvorn, M., G. W. Gill, G. F. Carlson, J. R. Bozell, and T. L. Steinacher
1999 Microevolution and the Skeletal Traits of a Middle Archaic Burial: Metric and Multivariate Comparison to Paleoindians and Modern Amerindians. *American Antiquity* 64:527–545.

Mann, R. W., and S. P. Murphy
1990 *Regional Atlas of Bone Diseases*. Charles C. Thomas, Springfield.

Mann, R. W., S. A. Symes, and W. M. Bass
1987 Maxillary Suture Obliteration: Aging the Human Skeleton based on Intact or Fragmentary Maxilla. *Journal of Forensic Science* 232:148–157.

Meindl, R, S., and C. O. Lovejoy
1989 Age Changes in the Pelvis: Implications for Paleodemography. In *Age Markers in the Human Skeleton*, edited by M. Iscan, pp. 137–168. Charles C. Thomas, Springfield.

Meindl, R. S., and C. O. Lovejoy
1985 Ectocranial Suture Closure: A Revised Method for the Determination of Skeletal Age at Death based on the Lateral-Anterior Sutures. *American Journal of Physical Anthropology* 68:57–66.

Meltzer, D. J.
1993 Pleistocene Peopling of the Americas. *Evolutionary Anthropology* 1:157–169.
1994 The Discovery of Deep Time: A History of Views of the Peopling of the Americas. In *Method and Theory for Investigating the Peopling of the Americas* edited by R. Bonnichsen and D. G. Steele, pp. 7–26. Center for the Study of the First Americas, Oregon State University, Corvallis.
1997 Monte Verde and the Pleistocene Peopling of the Americas. *Science* 276:754–755.

Mosch, C., and P. J. Watson
1996 The Ancient Explorer of Hourglass Cave. *Evolutionary Anthropology* 5:111–115.

Mullineaux, D. R.
1986 Summary of Pre-1980 Tephra-Fall Deposits Erupted from Mt. St. Helens, Washington State, U.S.A. *Bulletin of Volcanology* 48:17–26.

Neves, W., D. Mumford, and M. C. Zanini
1996 Cranial Morphological Variation and the Colonization of the New World: Towards a Four-Migration Model. *American Journal of Physical Anthropology* 22:176.

Neves, W. A., J. F. Powell, A. Prous and E. G. Ozolins
1998 Lapa Vermelha IV, Hominid 1: Morphological Affinities of the Earliest Known American. *American Journal of Physical Anthropology*, Supplement 26:169.

Neves, W. A., and H. M. Pucciarelli
1989 Extra-Continental Biological Relationships of Early South American Remains: A Multivariate Analysis. *Ciencia e Cultura* 41:566–575.
1991 Morphological Affinities of the First Americans: An Exploratory Analysis Based on Early South American Human Remains. *Journal of Human Evolution* 21:261–273.

Nichols, J.
1990 Linguistic Diversity and the First Settlement of the New World. *Language* 66:475–521.

Ortner, D. J., and G. J. Putschar
1981 *Identification of Pathological Conditions in Human Skeletal Remains*. Smithsonian Institution, Washington, D. C.

Owsley, D. W.
1998 Inventory Observations on the Kennewick Man Skeleton. *Bonnichsen et al. v. United States of America*, Plaintiffs' Supplemental Report on Transfer of the Skeleton, Appendix B. United States District Court for the District of Oregon, Dec. 10, 1998.

Owsley, D.W., and R. L. Jantz
1999 Databases for Paleo-American Skeletal Biology Research. In *Who Were the First Americans*, edited by R. Bonnichsen, pp. 79–196. A Peopling of the Americas Publication, Corvallis.

Powell, J. F., and W. A. Neves
1999 New Craniofacial and Dental Perspectives on Native American Origins. *Yearbook of Physical Anthropology* 42:153–188.

Powell, J. F., and J. C. Rose
1999 Report on the Osteological Assessment of the "Kennewick Man" Skeleton (CENWW.97.Kennewick). Report submitted to the National Park Service, U.S. Department of the Interior, Washington, D.C.

Preston, D.
1997 The Lost Man. *The New Yorker* 16 June:70–81.

Ray, V. F
1936 Native Villages and Groupings of the Columbia Basin. *Pacific Northwest Quarterly* 27:99–152.

Rowe, C. R.
1988 Dislocations of the Shoulder. In *The Shoulder*, edited by C. R. Rowe, pp. 165–291. Churchill, Livingston, New York.

Ruff, C. B.
1992 Biomechanical Analysis of Archaeological Human Skeletal Samples. In *Skeletal Biology of Past Peoples: Research Methods*, edited by S. R. Sanders and A. Katzenburg, pp. 37–58. Wiley-Liss, New York.
1994 Morphological Adaptation to Climate in Modern and Fossil Hominids. *Yearbook of Physical Anthropology* 37:65–107.

Ruff, C. B., E. Trinkaus, and T. W. Holliday
1997 Body Mass and Encephalization in Pleistocene *Homo. Nature* 387:173- 176.

Sandweiss, D. H., H. McMinnis, R. L. Burger, A Cano, B. Ojeda, R. Paredes, M. del Carmen Sandweiss, and M. D. Glascock
1998 Quebrada Jaguay: Early South American Maritime Adaptations. *Science* 281:1830–1832.

Schurr, T. G.
1999 A Molecular Anthropological View of the Peopling of the Americas. Paper presented at the Clovis and Beyond Conference, Santa Fe, New Mexico, October 30, 1999.

Scott, E. C.
1979 Dental Wear Scoring Technique. *American Journal of Physical Anthropology* 51:213–218.

Shiner, J. L.
1961 *The McNary Reservoir: A Study in Plateau Archaeology.* Bulletin No. 179:149–266. Bureau of American Ethnology, Smithsonian Institution, Washington, D.C.

Smith, B. H.
1984 Patterns of Molar Wear in Hunter-Gatherers and Agriculturalists. *American Journal of Physical Anthropology* 63:39–56.

Steele, D.G., and C.A. Bramblett
1988 *The Anatomy and Biology of the Human Skeleton.* Texas A&M University Press, College Station.

Steele, D. G., and J. F. Powell
1992 Peopling of the Americas: The Paleobiological Evidence. *Human Biology* 64:303–336.
1994 Paleobiological Evidence for the Peopling of the Americas: A Morphometric View. In *Method and Theory for Investigating the Peopling of the Americas*, edited by R. Bonnichsen and D. G. Steele, pp. 141–163. Center for the Study of the First Americans, Corvallis.
1999 Peopling of the Americas: A Historical and Comparative Perspective. In *Who Were the First Americans*, edited by R. Bonnichsen, pp. 97–126. A Peopling of the Americas Publication, Corvallis.

Stewart, T. D.
1962 Anterior Femoral Curvature: Its Utility for Race Identification. *Human Biology* 34:49–62.
1979 *Essentials of Forensic Anthropology.* Charles C. Thomas, Springfield.

Taylor, R. E., D. L. Kirner, J. R. Southon, and J. C. Chatters
1998 Radiocarbon Dates of Kennewick Man. *Science* 280:1171–1172.

Thwaites, R. G.
1904–1905 *The Original Journals of Lewis and Clark.* Dodd, Mead, New York.

Todd, T. W.
1921 Age Changes in the Pubic Bone I: The White Male Pubis. *American Journal of Physical Anthropology* 3:285–334.

Trinkaus, E.
1981 Neanderthal Limb Proportions and Cold Adaptation. In *Aspects of Human Evolution*, edited by C. Stringer, pp. 187–224. Taylor and Francis, London.

Trotter, M. and G. C. Gleser
1958 A Re-evaluation of Estimation of Stature based on Measurements of Stature Taken during Life and of Long Bones after Death. *American Journal of Physical Anthropology* 16:79–123.

Turner, C. G. II
1985 The Dental Search for the Native American Origins. In Out of Asia. *Peopling the Americas and the Pacific*, edited by R. Kirk and E. Szathmary, pp. 31–78. Journal of Pacific History, Canberra.
1990 Major Features of Sundadonty and Sinodonty, Including Suggestions about East Asian Microevolution, Population History, and Late Pleistocene Relationships with Australian Aboriginals. *American Journal of Physical Anthropology* 82:295–317.

Wakeley, L. D., W. L. Murphy, J. B. Dunbar, A. G. Warne, and F. L. Briuer
1998 *Geologic, Geoarchaeologic, and Historical Investigations of the Discovery Site of Ancient Remains in Columbia Park, Kennewick, Washington.* U. S. Army Corps of Engineers Technical Report GL-98-13. Waterways Experiment Station, Vicksburg, Mississippi.

Waldron, T.
1998 A Note on the Estimation of Height from Long-Bone Measurements. *International Journal of Osteoarchaeology* 8:75–77.

Waldvogel, F. A., G. Medoff, and M. W. Schwartz
1971 *Osteomyelitis: Clinical Features, Therapeutic Considerations, and Unusual Aspects.* Charles C. Thomas, Springfield.

Walker, R. A., and C. O. Lovejoy
1985 Radiographic Changes in the Clavicle and Proximal Femur and Their Use in the Determination of Skeletal Age at Death. *American Journal of Physical Anthropology* 68:67–78.

Warfel, J. H.
1974 *The Extremities.* 4th ed. Lea and Ferbiger, Philadelphia.

West, F. H. (editor)
1996a *American Beginnings: The Prehistory and Paleoecology of Beringia:* University of Chicago Press, Chicago.
1996b Beringia and New World Origins: The Archaeological Evidence. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by F. H. West, pp. 537–559. University of Chicago Press, Chicago.

Wilensky, A. O.
1934 *Osteomyelitis. its Pathogenesis, Symptomology, and Treatment.* Macmillan, New York.

Young, D. E.
1988 An Osteological Analysis of the Paleoindian Double Burial from Horn Shelter, Texas. *Central Texas Archaeologist* 11:11–115.

Notes

1. This permit was requested specifically, upon a suggestion from the COE, for recovery of the skeleton as part of a coroner's investigation. Their concern at the time was that recovery efforts might disturb nonskeletal archaeological materials. The permit was issued on July 30, retroactive to the date of discovery. Interaction with tribes was maintained through the COE (beginning on the day after the discovery), as was the Walla Walla District's practice.

2. Plaster was never in contact with the bone, nor did the use of polymers damage the bone or interfere with later reconstruction efforts, contrary to public statements by the Department of the Interior.

3. The COE had ordered that all study of the skeleton cease before comprehensive photos could be taken of the postcranial skeleton. This videotape was made as a fast alternative to still images, immediately before the bones were placed in lockup.

4. Researchers interested in working with or obtaining copies of any of this material should contact the author.

5. In his February 1999 investigation, Fagan (1999) inferred from CT scans taken at 2 mm resolution that the projectile point entered from the rear and below. I have seen the CT scans on which he bases this conclusion and find that my

original assessment, which is also founded on unaided visual observation of the point base, is correct.

6. The term "Caucasoid" is used in forensic cases as a means to facilitate identification of the dead. Historically, the term has been used within anthropology to refer to peoples that are either of western Eurasian origin or who resemble those populations in gross morphology. For example, the Ainu of Japan have long been labeled Caucasoid by some; the term "protocaucasoid" has been to refer to the Upper Cave male of China (Steele and Powell 1999), as well as to some of the early Paleoamerican material (Birdsell 1951). It was in this sense of gross morphology, not presumed origin, that I used the term.

7. Powell and Rose (1999) report pathologies they observed during a brief inspection of the skeleton in February 1999. Although our analyses concur on some points, they differ on others, particularly the number and placement of fractured ribs, direction of the projectile entry, location of arm fractures, and timing of various injuries. I do not review their analysis here in detail, but should note that I remain unconvinced by their assessment.

8. I use only males here because the Kennewick skeleton is male. Sexual dimorphism among these early people appears to be extensive, so commingling of males and females in the analysis could produce misleading results.

Received April 7, 1999; accepted September 9, 1999; revised November 15, 1999.