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December 30, 1998

Lt. Col. William E. Bulen, Jr.
U.S. Army Corps of Engineers
Walla Walla District
201 N. 3rd Avenue
Walla Walla, WA 99362-1876

Dear Colonel Bulen:

I have enclosed my analysis of geological data presently available for the Kennewick Site, Washington. This analysis is the one mentioned in the December 23, 1998 ARPA permit request letter to you from Gary Huckleberry and myself.

My conclusion is that geological test excavations at the Kennewick Site are absolutely necessary. The December 1997 reconnaissance fieldwork did not answer the questions we outlined in our original ARPA permit request dated August 26, 1997. The Huckleberry team's test excavations will resolve fundamental problems that remain regarding the Site's chronology, the three-dimensional geology of the terrace, and the depositional origin of the human skeletal remains.

Sincerely yours,

Thomas W. Stafford, Jr., Ph.D.
President & CEO
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ANALYSIS OF GEOARCHAEOLOGICAL DATA AND RESEARCH OBJECTIVES FOR THE KENNEWICK MAN DISCOVERY SITE, COLUMBIA PARK, WASHINGTON

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December 30, 1998

INTRODUCTION

On August 26, 1997, we submitted an application[1] to the Walla Walla District of the U.S. Army Corps of Engineers for an ARPA permit to authorize study of the site where the Kennewick Man skeleton was found (hereafter, the "Site"). Our permit application sought permission for us to conduct a multidisciplinary investigation of the Site to gather data for evaluating the contextual framework of the Kennewick Man discovery locality. To date, the requested ARPA permit has not been issued.

After the filing of our permit application, the Army Corps developed its own proposal for investigating the Site. The Army Corps' original proposal conceived that its investigations would be conducted in a series of phases. Members of the U.S. Army Corps of Engineers Waterways Experiment Station ("WES") conducted Phase One, a pedestrian survey of the Site, in October 1997. Phase Two was a limited geoarchaeological testing of the Site and was conducted between December 13 and December 17, 1997. Phase Three test excavations at the Site have yet to be conducted. Our research team was allowed to participate in the Army Corps' Phase Two activities on a limited basis. A report of our work and conclusions (hereafter referred to as the "Huckleberry et al. Report"[2]) was delivered to the Army Corps on March 23, 1998. On June 29, 1998, WES issued a preliminary report (hereafter the "Preliminary WES Report")[3] of its October and December 1997 Site investigations. The final WES report is dated August 20, 1998 and is referred to herein as the "Final WES Report."[4]

Our research team has made repeated requests to the Army Corps for issuance of the ARPA permit we applied for in August 1997. On July 7, 1998, we were informed that the requested per-

[1] Application for a Federal Permit under the Archaeological Resources Protection Act. "Columbia Park, Benton County, Washington Discovery Location of Kennewick Man Skeleton", filed by Gary A. Huckleberry, August 26, 1997 and submitted to the Department of the Army.

[2] Huckleberry, Gary., Stafford, Thomas W., Jr., and Chatters, James C. 1998. "Preliminary geoarchaeological studies at Columbia Park, Kennewick, Washington, USA." Report submitted to U.S. Army Corps of Engineers, Walla Walla District, March 23, 1998. 34 p.

[3] Wakeley, Lillian D., Murphy, William L., Dunbar, Joseph B., Warne, Andrew G. and Briuer, Frederick L. 1998a. Preliminary Report, June 29, 1998. "Geologic and Georcheologic Investigation of the Discovery Site of Ancient Remains in Columbia Park, Kennewick, Washington." Waterways Experiment Station. Report prepared for U.S. Army Engineer District, Walla Walla.

[4] Wakeley, Lillian D., Murphy, William L., Dunbar, Joseph, B., Warne, Andrew G. and Briuer, Frederick L. 1998b. "Geologic, geoarchaeological, and historical investigation of the discovery site of ancient remains in Columbia Park,

mit "cannot be authorized at this time."[5] Ms. Kirts' letter invited us to consider revisions to our permit application "... based on the results of the Phase 2 site study", and stated that "Before an agency decision can be made on your request, we will consider any revisions to the permit application that you may propose and ask for comment from the regional tribes."[6]

The purpose of the present analysis is to discuss whether or not test excavation of the site is still needed to resolve the research objectives set out in our August 1997 permit application.[7] We will address in a separate document whether or not it is desirable to revise our proposed excavation procedures based on what has been learned concerning the Site following Phase Two activities.

Phase Two: Limitations and Significance

The Army Corps' Phase One and Phase Two investigations of October 1997 and December 1997 have not eliminated or reduced the need for test excavations of the Site as proposed in our ARPA permit application. There are several reasons why that is true. First, the Corps' investigations were designed to accomplish very limited goals that did not include obtaining the full range of data needed for resolving the research objectives set out in our permit application. Second, major limitations were imposed on the type of activities that could be carried out during Phase Two.[8] Those restrictions severely impacted the quantity and the quality of the data obtained by both geological teams. Third, the data obtained during Phase Two must be tested by further investigation of the Site. It is a fundamental principle of science that interpretations of data can not be accepted as valid unless the data are subject to confirmation and refutation by other investigators. The essence of the scientific principle is that conclusions must be tested and retested by different investigators.

In the March 1998 Huckleberry et al. Report, we specifically discussed the need for further site excavations.[9] Our recommendation was: *"More data are critically needed to fully assess the ge-*

Kennewick, Washington." Report prepared for U.S. Army Engineer District, Walla Walla, Washington. September 20, 1998. 69 pp., 20 figs, 9 appendices.

[5] July 7, 1998 letter from Linda Kirts to Dr. Gary Huckleberry.

[6] Ibid.

[7] It is imperative that test excavations be undertaken as soon as possible. Natural conditions protected the skeleton for at least the past 9000 years or more. However, these favorable hydrologic and sedimentary conditions were compromised when McNary reservoir was constructed and water levels were elevated. Even more deleterious to the Site's long-term preservation was the recent burial of the discovery site's shoreline with tons of rock, dirt and other debris that will adversely affect the preservation of any remaining organic or cultural materials encased within the once pristine terrace sediments.

[8] For a summary of those limitations see Huckleberry et al. 1998, pp. 23-25.

[9] Huckleberry et al. 1998, pp. 20-23.

ology of the Kennewick Man site."[10] Our report also stated: *"Formal test excavations in the terrace, as Phase 3, should proceed immediately."*[11]

The Army Corps' research team reached identical conclusions. For example, the Final WES Report stated:

> *"The [geologic] work was limited to the exposed reservoir bank and could not answer many research questions about the regional geologic setting and prehistoric land use."*[12]

Even more to the point, the WES team acknowledged that:

"A study limited to the 2-dimensional shoreline exposures did not provide enough information to interpret all features of the 3-dimensional landform and stratigraphic sequence. Because of public and scientific interest in the ancient remains, more complete characterization of site geology is warranted so that the site can be understood and discussed in a regional holistic setting."[13]

Likewise, the WES team also concluded:

"Full characterization of the geologic setting and landform at the Kennewick site probably will require invasive study."[14]

Most recently, Dr. Wakeley emphasized that the previous reconnaissance didn't provide time to investigate many geological occurrences, and that "…it's [the occurrence of a paleosol] among the strong reasons to go back and do a more in-depth investigation [at the Site]."[15]

I feel that "probably" is too mild of a word to describe a situation where no three-dimensional data are available for a Site of such national scientific importance. Test excavation of

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[10] Ibid., p. 22.
[11] Ibid., p. 25.
[12] Wakeley et al. 1998b, p. xv.
[13] Ibid., p. 59, ¶ 3.
[14] Wakeley et al. 1998b, p. 59, ¶ 5.
[15] Diedtra Henderson, Who's right about Kennewick Man", The Seattle Times, Tuesday, December 8, 1998, Science

the Site is not "probably" necessary, it is *absolutely essential.* Further study of the Site should include, at a minimum, the kinds of test excavations proposed in our ARPA permit application.

Geoarchaeological testing at the Kennewick Discovery Site is mandatory to resolve geological questions crucial to the Site's interpretation. Among other problems, the radiocarbon chronology of the Site has not been established. There are questions regarding the chronology of sediments underlying the Mazama Ash, i.e., for all strata dating older than ca. 7000 yr. B.P. In addition, information about the Site's geoarchaeological potential is insufficient because less than 0.6 m^3 of the terrace's approximately 70,000 m^3 was investigated. Furthermore, the origin, depositional environment, and reason for preservation of the human skeleton are unknown except in a general, regional sense. Phase Two fieldwork examined only 6 linear meters of a possible 350 meters of shoreline exposures. Only 0.6 m^3 of sediment volume was examined, an amount that represents less than 0.0001% of the sediment volume easily testable. Our proposed excavations will resolve the Site's geological history in a manner that additional reconnaissance surveys or regional analyses will not.

Research Objectives

In our August 1997 permit application we identified six issues that we believe must be resolved to evaluate the geoarchaeological potential of the Kennewick Man discovery site.[16] These six objectives are:

Objective 1 **Age of the Site**

Whether the age of the Site is consistent with the radiocarbon age of the skeleton.

Objective 2 **Deposition of the Skeleton**

Whether the skeleton was deposited at the Site due to an intentional burial or to other causes.

Objective 3 **Potential Site Disturbance**

Whether the Site has been disturbed by geological, biological or cultural

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Section, A8, Column 3.

[16] Huckleberry, G.A. (1987) ARPA permit request Exhibit B, Item 2.

factors following initial deposition of the skeleton.

Objective 4 **Preservation of the Skeleton**

What factors may have contributed to preservation of the skeleton over time.

Objective 5 **Human Occupation of the Site**

Whether there was human occupation of the Site at the time of, prior to, or subsequent to deposition of the skeleton.

Objective 6 **Conditions Affecting Radiocarbon Dates**

Whether the Site is subject to any unusual conditions that might affect the reliability of radiocarbon dates taken from the skeleton or other organic materials (if any are found).

Objective One: Age of the Site

The first research objective identified in our permit application was: *Whether the age of the Site is consistent with the radiocarbon age of the skeleton.*

The Army Corps' study team also identified this issue as an important research objective.[17] The Final WES Report states: "Phase Two study established that the geologic age of the site is consistent with the reported 9,000-year age of the remains."[18] I do not agree that geologic ages, precise to ±100 years, have been established for the Site. I do agree that the geomorphology and stratigraphy at the Site appear to be compatible with the regional history for late Pleistocene and Holocene Columbia River deposits.[19] Therefore, on an overall, *regional* scale, the age of the Site is consistent with the radiocarbon age of the skeleton. However, the dating precision needed at the

[17] Wakeley et al. 1998b Executive Summary, p. iii.
[18] Ibid., pp. xv; 57; 59.
[19] Chatters, J.C. and K.A. Hoover (1992). "Response of the Columbia River Fluvial System to Holocene Climatic Change" Quaternary Research, 37:42-59. Hammett, H.H.. 1977. Late Quaternary Stratigraphy and Archaeological Chronology in the Lower Granite Reservoir Area, Lower Snake River, Washington. Ph.D. Dissertation, Washington

Site is ±100 years, not the ±1000 to 2000 years obtained by using regional terrace stratigraphy. Consequently, I do not believe that the Site's geologic age has been established accurately enough to reconstruct its depositional history at a resolution appropriate for understanding the full context of the skeleton. More specifically, we do not have sufficient data to determine how old the individual strata are at the Site, and what is the reconstructed stratigraphic location (± 5 cm vertically) for the human skeleton. These questions cannot be resolved without test excavations of the Site.

Radiocarbon ages on organic materials from a sedimentary stratum are customarily used as a reliable estimate of a stratum's geologic age. In the present situation, the radiocarbon age obtained from the skeleton is not sufficient by itself to establish the age of its original enclosing sediments. First, the skeleton's geologic age could differ from the age of its enclosing sediments if the human skeleton was an intrusive burial. Second, the exact stratum yielding the human bones has not been identified definitively. Even if the skeleton's radiocarbon age is absolutely accurate and the remains represent a primary depositional event, the skeleton's 8410±60 yr. B.P. radiocarbon date can not be applied to an approximately 50 cm thick interval within Unit IV. This ca. 50 cm thick unit, which our investigations indicate contains multiple strata, is believed to be the bed yielding the human remains. Third, a single radiocarbon date, whether on bone, sediment or shell, is not a conclusive age estimate for a stratum. Accepted radiocarbon procedure is to date different organic materials from one stratum, or different chemical fractions of one organic material. Resolving these issues requires test excavations of the Site.

Specific problems and unanswered questions regarding the Site's chronology follow.

Mazama Ash Bed

The volcanic ash exposed at the western limits of the Site has been identified as Mazama Ash, which elsewhere has been dated to approximately 6700 yr. B.P.[20] This tephra or volcanic ash is believed to overlay stratigraphically the sediments that yielded the Kennewick human skeleton. Unfortunately, this time-stratigraphic marker bed could not be appropriately used during the Phase Two investigations due to governmental restrictions placed on fieldwork. In December 1997, Staf-

State University, Pullman. Frixell, R. (1973) Salvage of Geochronological Information in the Wells Reservoir Area, Washington, 1964-1972. Laboratory of Anthropology, Washington State University, Pullman.

[20] Wakeley et al. 1998b, p. 35.

ford and Chatters[21] were able to trace the volcanic ash continuously from CPP-095 to CPP-070, a position 25 to 30 meters from the skeleton's estimated origin near CPP-054. Because government-imposed restrictions prevented tracing the ash through inspection of continuous, cleaned stratigraphic sections, the WES data on the ash layer could be presented only as fence diagram correlations[22], rather than continuous stratigraphic profiles. As a result, it is *not* known how the Mazama Ash physically relates to sediments at CPP-054, the hypothesized origin for the human skeleton. The shoreline exposures have now been obliterated by the Corps' actions in burying the discovery site beneath 500 tons of rock, dirt and other debris. Fortunately, the Mazama Ash can still be traced by excavating a few meters inland (south) from the now-buried shoreline. This technique will establish conclusively if the Mazama Ash extends as far west as CPP-054. When Stafford and Chatters correlated the Mazama ash towards CPP-054[23] they had to infer that faint, disaggregated remnants of Mazama Ash were in situ and that the ash fragments did not represent tephra that had been reworked thousands of years later. This was a working field hypothesis that needs to be confirmed. If it is not confirmed, questions will remain whether the ages for sediments underlying the Mazama Ash are the same or significantly different from those presently inferred.

Carbonate Soil Horizon (Concretion Zone)

Both the Huckleberry et al.[24] and WES[25] reports concluded that the human skeleton was probably derived from the upper 10 to 20 centimeters of a pedogenic (soil) carbonate horizon. This unit is termed Upper Unit II[26] or Unit IV[27] in their respective reports. Identifying this physically distinct accumulation of irregular, 1 to 2 cm long carbonate concretions was a significant accomplishment of the Phase Two project and could aid in future interpretation of the Site if more data are ever obtained. However, it is important to emphasize that this geological feature cannot be used as a time-stratigraphic marker having the ±100 years or less precision needed for understanding the Site's stratigraphic history.[28] The carbonate concretion zone extends upstream (westward) to the Ma-

[21] Huckleberry et al. 1998, Fig. 5.
[22] Wakeley et al. 1998b, Fig. 13.
[23] Huckleberry et al. 1998, Fig. 5.
[24] Ibid., Fig. 5; p. 20 ¶ 2.
[25] Wakeley et al. 1998b, p. 45, ¶ 2.
[26] Huckleberry et al. Report, Fig. 5: p. 20, ¶ 2.
[27] Wakeley et al. 1998b, p. 58, ¶ 3.
[28] Ibid., p. 34, ¶ 4.; Fig. 13.

zama Ash exposure at CPP-334. The carbonate is a postdepositional, pedogenic accumulation of calcium carbonate that represents an ancient, buried, soil B-horizon. The sediment's permeability, porosity, primary bedding structures, internal stratification, and vertical distance from the modern ground surface and water table determine the vertical position of the carbonate horizon. A carbonate accumulation zone can occasionally parallel a depositional stratum and give a Bca horizon the appearance of a time stratigraphic unit. However, a Bca horizon should *never* be used for more than regional stratigraphic correlations on the scale of plus-or-minus several thousands of years, or at best, several hundreds of years.

The true significance of this carbonate horizon is undetermined until its distribution throughout the Site has been mapped accurately and until its age has been established. During Phase Two, the WES research team collected data that contribute to the sediment's chronology. Sediments containing the carbonate concretions yielded a 9010±50 yr. (WW-1626) radiocarbon measurement.[29] Although this radiocarbon measurement is similar in years to that measured directly on the human bone (8410±60 yr.; UCR3476/CAMS-29578)[30], this *numerical* similarity does not imply *geological-age* similarity. Chemical testing of the carbonate concretions is required before any correlations can be made between its age and the age of the skeleton. The greatest source of error is the physical location of the WW-1626 sample, which was taken from the top 10-20 cm of Vibracore core CPC-059.5. The sample's proximity to the modern surface could easily have contaminated the sediment with modern or younger sediment carbon. Furthermore, the actual chemical fraction dated as WW-1626 is unstated and could be any of at least five different chemical fractions, including: a) total sediment, b) total humates, c) humic acids, d) fulvic acids, or e) humins. Different chemical fractions from the same sediment can yield very different radiocarbon measurements.[31] These individual ^{14}C measurements can be drastically different from other sediment fractions or from fossil bone in the same stratum.[32] In addition, there is an unexplained age inversion for the two stratigraphically low-

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[29] Ibid., p. I11.
[30] Taylor, R.E., Kirner, D.L., Southon, J.R., and Chatters, J.C. 1998. *Science*, **280**: 1171-1172.
[31] Stafford, Thomas W., Jr., 1998. "Radiocarbon Chronostratigraphy". In: *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas*, Michael B. Collins, ed., Chapter 25: Archeological Features and Technical Analyses, Volume IV, pp. 1039-1066. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin and Archeological Studies Program, Report 10, Environmental Affairs Department, Texas Department of Transportation, Austin.
[32] Muhs, D.R., Stafford, T.W., Jr., et al. 1997. "Late Holocene eolian activity in the mineralogically mature Nebraska Sand Hills." *Quaternary Research*, **48**:162-176. Muhs, D.R., Stafford, T.W., Jr., 1997. "Holocene eolian activity in

est radiocarbon dates obtained at the Site and there is strong evidence for old-carbon reservoir effects (see following section discussing sediment ^{14}C dates.) Consequently, the age of the carbonate horizon is not established and the present set of sediment radiocarbon measurements can not be used to attribute the human remains to a specific stratum.

A problem for additional dating of the carbonate horizon is that accurate radiocarbon ages can not be obtained from the calcium carbonate phase that forms the carbonate concretions. The reason for this is that the initial ^{14}C activity, expressed as fraction modern (Fm), is unknown for the CO^{-3} in the Bca carbonate nodules. It is unknown how much of the total CO^{-3} in the carbonate horizon is represented by modern carbon or carbon having no detectable ^{14}C. Postdepositional alteration (carbonate exchange) can alter the carbonate's original ^{14}C content. This carbonate alteration can be by modern carbon, ancient carbon, or a combination of carbon from different sources. Consequently, a radiocarbon date based on total carbon is only a weighted average of ^{14}C from all sources contributing to the sample's ^{14}C content. Such a radiocarbon measurement does *not* establish the geologic age of the sediment from which the carbon was derived until the relationship is known between a specific carbon phase's ^{14}C content and the time-of-deposition. Because of these factors, the WW-1626 radiocarbon measurement should not be considered anything other than a preliminary, and very tentative, chronological estimate. Further testing of the Site is needed.

Radiocarbon Dates on Fresh Water Mollusk Shell

As part of the Phase Two investigations, the WES research team also obtained two radiocarbon measurements on fresh water mollusk shells (either one or a combination of the species *Gonidea angulata* or *Margaratifera falcata*).[33] We agree with the decision of the WES research team to request radiocarbon dates on these mollusk shells. Due to governmental restrictions on what activities could be conducted, these shells were virtually the only datable materials available to the WES team during Phase Two. We caution against over interpreting these shell radiocarbon measurements, which were 6510±60 yr. (Beta-113838) and 6090±80 yr. (Beta-113977).[34] The radiocarbon ages of these shells could be significantly different from their time-of-death in years B.P. First,

the Minot dune field, North Dakota." *Canadian Journal of Earth Science*, vol. **34**:1442-1459. Stafford, T.W. Jr. et al. 1991. "Accelerator radiocarbon dating at the molecular level." *Journal of Archaeological Science*, **18**:35-71.
[33] Wakeley et al. 1988b, p. C4.
[34] Ibid., pp. 41; I2

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the carbonate comprising the aquatic mollusk shell can have significantly less radiocarbon compared to the amount of ^{14}C in atmospheric CO_2 when the mollusk was living. This environmentally derived carbon is termed "old carbon" and is often bicarbonate derived from bedrock limestone dissolved into the groundwaters. There are at least two sources of ancient carbonate in the study area. One source is the Pliocene Ringold Formation, which contains freshwater limestones, and the second includes limestone deposits in the Rocky Mountains of northwestern Montana; either source would contribute carbon that contains no ^{14}C. The reservoir effect alters the shell's radiocarbon age because geological limestone carbon used to form mollusk shell $CaCO_3$ contains significantly less radiocarbon than the atmosphere when the animal was alive. The expression "less radiocarbon" means that the $^{14}C/^{12}C$ ratio in stream waters is smaller than that ratio in the atmosphere. This disequilibrium between water and atmosphere ^{14}C sources causes shells to have less radiocarbon than terrestrial organisms living at the same time. The net effect is that ^{14}C dates on shells can be "older" than the mollusk's true geological age. This geochemical condition is the "reservoir effect." It is measured quantitatively by two methods, either by ^{14}C dating mollusk species living in the river today, or comparing a fossil shell's carbonate ^{14}C age with an absolute geologic age determined independently for the mollusk.

Second, mollusk shells from carbonate-bearing sediments or from sediments where pedogenic or groundwater carbonate are common, as at the Kennewick Site, are susceptible to postmortem exchange of their indigenous carbonate with foreign (exogenous) carbonate. This secondary carbonate can have radiocarbon contents ranging from modern values to undetectable, the latter representing carbon from geologically ancient carbonates. Because modern rainwater and ancient groundwaters can mix in varying proportions, the apparent age of the secondary carbonate is unknown unless there are independent age determinations available for the shells. It is widely known that radiocarbon measurements on shells from the Columbia River system often differ by thousands of years from radiocarbon dates on charcoal associated with these shells.[35] AMS radiocarbon dating of shell protein (conchiolin) is one direct method for assessing the amount of secondary carbonate exchange. Although radiocarbon ages for the shells are *numerically* consistent for a stratum overlying the Ma-

[35] Chatters, J.C. (1986) The Wells Reservoir Archaeological Project, Washington, Volume 1, Summary of Findings, Central Washington Archaeological Survey, Archaeological Report 86-6. Central Washington University, Ellensburg. Chance, D.H. et al, (1989) Archaeology of Hatiuhpuh, Alfred W. Bowers Laboratory of Anthropology, University of Idaho, Moscow.

zama Ash, reservoir effects and diagenetic factors preclude the shell dates from being used as absolute geologic ages. Further testing of the Site is needed.

Radiocarbon Dates on Sediments

Four radiocarbon measurements were obtained on sediment samples from a single Vibracore (CPC-059.5).[36] Ordered from stratigraphically highest to lowest, the ages were: 9010±50 yr. (WW-1626) on sediments from 10-20 cm core depth; these sediments were from a soil carbonate horizon believed to be the one yielding the skeleton. The stratigraphically lower dates and their depths below core top were 12,460±50 yr. (WW-1737) at 130-138 cm; 15,330±60 yr. (WW-1627) at 190-200 cm; and 14,560±50 yr. (WW-1738) at 220-229 cm.[37] These dates could be potentially significant for understanding the Site's chronology and geology, but further testing is needed before their actual significance can be determined. At this point, the sediment dates should be considered preliminary, suggestive data only. In this regard, the following considerations should be kept in mind: a) the uppermost sample, at 10-20 cm depth from the core top, is too close to modern land surfaces and could have been contaminated by younger carbon, b) no description is given for the chemical fraction used for radiocarbon dating the sediments, b) the measurements have estimated, not measured $\partial^{13}C$ values, c) there are large age inversions for the two stratigraphically lowest dates, and d) the two oldest age estimates predate late Pleistocene catastrophic floods that should have scoured the valley of any sediments dating older than 12,000 to 14,000 radiocarbon years old.[38]

The age inversions and excess geologic ages may be due to a combination of a) ancient carbon being incorporated into the sediment during deposition, b) unrecognized bioturbation, c) groundwaters circulating unknown quantities of ancient and modern soluble carbon, d) continuous immersion of the sediments in reservoir waters of unknown radiocarbon content, and e) variations in the apparent geological ages of the different chemical phases comprising the total sediment. Further excavation and coring of the Site are needed to assess these factors and to determine the origin of these age discrepancies. Until this is done, the sediment ^{14}C measurements taken during Phase Two can only

[36] Wakeley et al. 1998b, fig. 17.
[37] Ibid., p. I111, p. I113.
[38] Wakeley et al. 1998a. p. 43.

be considered age *estimates*, not absolute geologic ages. Most importantly, no single sediment ^{14}C measurement can be accepted or rejected[39] until valid geochemical reasons are given.

The apparent similarity of the human skeleton's radiocarbon age, 8410±60 yr. (UCR-3476/CAMS-29578) to the 9010±50 yr. (WW-1626) sediment date should be considered fortuitous until proven otherwise. We understand the WES team's decision to discard the sediment ^{14}C dates from the lower half of core CPC-059 as unreliable.[40] Until further data are obtained, the same treatment should be applied to all sediment radiocarbon dates from the Site.

Overall Geochronological Considerations

Only one credible geologic age value is presently available for stratigraphy at the Kennewick Discovery Site. This age is from the Mazama Ash, a tephra that apparently overlies stratigraphically the human skeleton's presumed geologic stratum. Although the radiocarbon age that was obtained for the Kennewick human skeleton's bone is probably accurate, the stratum yielding the human bones has yet to be determined to within 5 cm vertically. Until that stratigraphic assignment is made, the skeleton's age cannot be used to date any of the sediments. Furthermore, until more data have been obtained, the existing sediment and shell radiocarbon dates have too many uncertainties regarding reservoir effects, diagenesis, and bioturbation for them to be used for relocating the human remains stratigraphically. This conclusion is the same as L. Wakeley's, who recently stressed "... that there could be errors in the [radiocarbon] numbers." and that "... the report — designed to answer a few key questions — doesn't substitute for more exhaustive, controlled radiocarbon tests from the site."[41]

Objective Two: Deposition of the Skeleton

Our second research objective is: Whether *the skeleton was deposited at the Site due to an intentional burial or to other causes.*

[39] Wakeley et al. 1998b, p. 47.
[40] Wakeley et al. 1998b, p. 47.
[41] Diedtra Henderson, Who's right about Kennewick Man", The Seattle Times, Tuesday, December 8, 1998, Science Section, A8, Column 2.

Because of government-imposed restrictions, the December 1997 Site study was unable to gather data specifically directed to this issue. As we noted in our March 1998 report, what little data are available suggest the skeleton was deposited at the site due to natural causes, rather than by deliberate, human activities such as a burial.[42] However, as we also noted, there are insufficient data to resolve this issue satisfactorily.[43] The Army Corps' study team agrees that neither intentional burial nor natural burial is established.[44] They suggest that it may be possible to resolve this issue by analyzing sediment and carbonate adhering and cemented to the skeleton.[45] Analyses of adhering-sediment particles can provide important data, and should be conducted. However, these analyses alone will not provide the needed data unless the sediments from the skeleton can be confidently tied to a specific stratum whose geologic age and depositional history have been clearly established. The latter questions cannot be resolved without appropriate test excavations at the Site.

At present, the geologic origin of the human skeleton can be described only as flood plain sediments. The sediments presumably yielding the human skeleton are too fine-grained to be channel sediments, but the sedimentological and geomorphic location of the skeleton within the fluvial system are otherwise unknown. Traces of climbing ripples, which indicate flood stage sedimentation, are preserved in sediments overlying the skeleton's presumed stratigraphic unit.[46] However, primary depositional structures are absent in the carbonate horizon believed to have contained the skeleton. The Site's sediments were examined only parallel to the river axis. Three-dimensional data are the crucial missing information needed to locate the human remains geomorphically within Columbia River floodplain sediments. Without suitable stratigraphic profiles perpendicular to the stream axis, the actual depositional environment for the skeleton must be described as unknown.

Objective Three: Potential Site Disturbance

The third research objective identified in our permit application is: *Whether the Site has been disturbed by geological, biological or cultural factors following initial deposition of the skeleton.*

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[42] Huckleberry et al. 1998, p. 21.
[43] Ibid., p. 21.
[44] Wakeley et al. 1998b, p. 58.
[45] Ibid., p. 59

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At present, there are insufficient data to resolve this issue. Phase Two produced some data relating to post-depositional processes affecting the Site. However, these data are *not* sufficient to determine the full extent of Site alterations. The data are equivocal because only six meters total of bank sediments were examined along a 350-meter long, vertical exposure oriented parallel to the valley's long axis. Moreover, only 0.6 m^3 of 70,000 m^3 of sediments were examined. This volume represents less than 0.0001% of the sediment that could have been tested. This small sample volume is totally inadequate for describing reliably the lateral variability of strata in the Site. Moreover, because of restrictions imposed by non-scientists from the government, the only information obtained during Phase Two concerning Site geology perpendicular to the river axis was from a single core sample used for radiocarbon dating. This core does not provide adequate evidence for erosional features, soil horizons and human disturbances over the past 10,000 years. To be reliable, inferences must be based on three-dimensional data, not widely spaced two-dimensional sediment exposures.

Objective Four: Preservation of the Skeleton

Our fourth research objective is: *What factors may have contributed to preservation of the skeleton over time?*

The preservation of the skeleton is due to a combination of sedimentary and geochemical factors. However, the specific factors that were operative in this case cannot be definitely determined until the skeleton's actual stratigraphic origin is established. Some of the factors that may have contributed to its preservation are: a) presence at the Site of alkaline, calcium carbonate-rich sediments that favor excellent physical and chemical preservation of bones, b) presence at the Site of fine-grained sediments (clayey silts and clays) that have low permeabilities and therefore inhibit waters from percolating through the fossil bone, c) a secondary (soil) carbonate horizon, which further protected the bones by enclosing them in an alkaline environment, and d) the terrace sediments being above fluctuating water tables that would otherwise have repeatedly leached the fossil bones. These observations, however, have not been fully explored and more data are needed.

[46] T.W. Stafford, Jr. December 13-17, 1997 field notes.

The skeleton's excellent physical and chemical preservation portend a high probability of equally good preservation for any other bones deposited within the terrace. These potentially favorable conditions for the preservation of bone and shell fossils are another justification for proceeding with geological testing of the site. It is imperative that such testing be conducted as soon as possible. The skeleton's preservation over approximately 9,000 years is due to the fortuitous circumstance that an environment favorable to preservation had protected the bones. However, the Army Corp's recent Site burial project has altered the Site's hydrologic and geochemical conditions. These alterations could affect the survival of other fossils that might be present at the Site and these geochemical changes could jeopardize the prospects for future radiocarbon dating of the Site.

Objective Five: Human Occupation of the Site

Our fifth research objective is: *Whether there was human occupation of the Site at the time of, prior to, or subsequent to deposition of the skeleton.*

Insufficient data were obtained during the December 1997 site study to resolve this issue.[47] In fact, government restrictions prevented any systematic effort to investigate for the presence of past human occupations at the Site. The minuscule volume of terrace sediment examined precluded the possibility of addressing this issue. The Corps' decision to limit geoarchaeological studies to only 6 total meters of shoreline and 0.6 m^3 of a 70,000 m^3 terrace guaranteed that no viable assessment would be accomplished.

In this regard, it should be noted that what few sediments were examined during Phase Two were "dry" screened through coarse (1/4") or less frequently, smaller (1/8") mesh screen. The mesh size of these screens, combined with the plastic and sticky nature of the clayey sediments at the Site, prevented the discovery of small vertebrate and invertebrate microfossil remains and of small lithic debitage that would have been definitive evidence for human occupations. Future investigations at the Site should employ wet screening through 1 mm mesh screens. Such screening is more

[47] Huckleberry et al. 1998, p. 21; Wakeley et al. 1998b, p. 64.

likely to uncover evidence for or against human occupation at the Site and will provide important paleoecological information from small mammal and other vertebrate fossils.

We also caution against efforts to draw final conclusions from the few basalt artifacts that were recovered. These artifacts were found at a lower elevation than the stratum apparently yielding the human skeleton.[48] It is premature to conclude that these artifacts originated from a stratum identical to or beneath the bed yielding the human remains. It is more likely that the artifacts originated in younger, overlying sediments and were redeposited at a lower elevation by slumping. It is often difficult to differentiate slumped sediments from in situ sediments when both are wet and have nearly identical colors and textures. Furthermore, standard precautions of removing secondary sediments from the profile before screening were not taken. Such precautions would have eliminated the possibility of including slumped sediments in the screened sample. Further investigations are needed before artifacts are attributed to strata as old or older than the one yielding the Kennewick Skeleton.

Moreover, because only a two-dimensional view was obtained of the terrace geology, it was impossible during Phase Two to undertake an examination of horizontal surfaces that could have been occupation horizons. Intact soil A-horizons are least likely to be preserved the closer one approaches the river channel. Because the shoreline exposure is parallel to the valley axis, the sediments there will have the *least* chance of showing how stable geomorphic surfaces trend inland. Along shoreline bank exposures, there is no intact soil A-horizon associated with the carbonate Bca horizon that is thought to have held the human bones. If the A-horizon is preserved further inland, it is possible that one or more occupational levels could be preserved. Such occupation levels, if they exist, could provide important information concerning the cultural origins of the skeleton. However, these possibilities cannot be examined without test excavations at the Site.

[48] Wakeley et al. 1998b, p. 42, ¶ 4.

Objective Six: Conditions Affecting Radiocarbon Dates

The sixth research objective identified in our permit application is: *Whether the Site is subject to any unusual conditions that might affect the reliability of radiocarbon dates taken from the skeleton or other organic materials (if any are found).*

This question was asked because some people have suggested that radioactive contamination from the Hanford Facility might have biased or compromised the radiocarbon dates.[49] Were nuclear plant contamination sources present, they would cause enormous age errors. However, this contamination would cause radiocarbon ages to appear dramatically *younger*, not older than the correct geologic age. Consequently, Hanford Facility contamination is absent.

In our report, we concluded that there were no *unusual* conditions that would affect radiocarbon dates.[50] However, as noted above, there are several unresolved potential error sources affecting the sediment and shell radiocarbon dates. These errors are from carbonate reservoir effects for the mollusk shells, old-carbon reservoir effects for the sediments, bioturbation of sediments, and postdepositional diagenesis of both the shells and sediments. These are pervasive, yet *normal* and *common* geochemical circumstances that can be readily quantified and evaluated if adequate field and laboratory tests are permitted. The required evaluation procedures are: first, an understanding of the geochemical cycles and histories for each carbon phase, second, use of laboratory methods that isolate the chemical fraction(s) best suited for dating, and third, obtaining the experimental field data needed to identify diagenesis, bioturbation, and organic carbon cycling within the sedimentary deposit. These field and laboratory practices are commonly performed in situations like the present one.[51] Their omission from the Phase Two studies was due to government-imposed restrictions. The absence of this experimental data prevents the existing radiocarbon data from being used with accuracies any better than ±1000 years.

[49] Vine Deloria, "Do scientists have rights to all finds?" The Denver Post, November 29, 1998 sec. G, pp. 1-2.
[50] Huckleberry et al. 1998, p. 21.
[51] Stafford, T. W. (1998) "Radiocarbon Chronostratigraphy".

CONCLUSIONS

The geological reconnaissance studies conducted at the Kennewick Man Discovery Site during Phase Two demonstrated that a Holocene to late-Pleistocene age terrace existed, that most sediments were older than the 6700 yr. B.P. Mazama Ash, that the sediments were Columbia River floodplain deposits, and that at least one period of soil formation was represented. These conclusions follow those found in published literature for the region during the past twenty-five years. These studies have far from exhausted the rich scientific potential of the Kennewick Site.

Of the six research objectives identified in our ARPA permit application, only one, the minimum site age (6700 yr.), has been established by using quantitative data.[52] There are no credible data regarding three objectives: a) whether the skeleton represents a natural or intentional burial, b) whether or not there were human occupations that might have left artifacts establishing the skeleton's cultural affiliations, and c) what factors might have affected the reliability of radiocarbon dating. Two objectives were only partially answered: a) whether or not biogeochemical factors affected the Site and b) what factors contributed to the skeleton's excellent preservation. Only a very small fraction of the knowledge readily accessible from the Kennewick Site has been acquired. This deficiency is due entirely to the restrictions placed on *both* the WES and Huckleberry et al. geological teams by non-scientists from the U.S. Government. Phase Two geoarchaeological studies at the Site were inadequate and incomplete because government officials prohibited *both* scientific teams from using accepted Quaternary geology field methods to evaluate the Kennewick Site. The restrictions leading to this diminished scientific effort were imposed *upon* the scientists and despite the scientists' requests for customary and adequate access to the Site and use of standard methods of scientific inquiry.

Examples of such restrictions include the following:

1. Collaboration between the Huckleberry et al. and WES teams was discouraged, if not explicitly forbidden. Combining the respective teams' geological and analytical talents would have

[52] Wakeley et al., 1998b, Appendix H, "Tephrochnology Report", pp. H1-17.

completed the research objectives more completely and accurately. Instead, field, laboratory, and clerical efforts were replicated, and analytical resources available to WES were not used by all scientists analyzing the Site. In addition, the stratigraphic and chronological expertises within the Huckleberry et al. team were not solicited because government restrictions minimized information sharing. Had each team's individual talents and resources been shared, the Site's geology would be known in far greater detail than it is presently.

2. The length of shoreline and the volume of sediment examined in December 1997 were not suitable for a site of such scientific importance. Government restrictions on fieldwork resulted in only 1.7% of the shoreline being examined and less than 0.6 m^3 of 70,000 m^3 of sediment volume being investigated. Examining such minuscule percentages of a readily accessible site is contrary to accepted Quaternary geology procedures. Virtually all of the shoreline was accessible; however, continuous stratigraphic profiling was prohibited even though it is a universally accepted practice in Quaternary geology. Other commonly conducted practices that were not performed included removing adequate amounts (>10 cm) of sediment from vertical walls to minimize physical and geochemical contamination of samples taken for size and geochemical analyses; scrupulous cleaning of horizontal and vertical surfaces to eliminate contamination by sloughed sediments; and thorough collection of shorelines and beach sediments to recover artifacts and fossils eroded from the banks. No reliable data are available on the skeleton's origin, deposition, preservation, and association with other cultural remains because less than 0.0001% of the Site volume has been examined. There were no environmental, geological, or archaeological reasons that prevented an adequate geological assessment of the Site from being made.

3. One major consequence of these government-imposed restrictions was that it proved very difficult to collect radiocarbon samples in an accurate, contamination-free manner. In addition, it was impossible to collect multiple samples on which multiple investigators could perform confirming tests. Such confirmatory tests are a routine, accepted practice and are needed to ensure that any results obtained have the reliability needed for correct interpretation of the Site's chronology and geology.

4. Other examples of study and testing restrictions imposed by the government are listed in our March 1998 report.[53]

Test excavation of the Site is more essential than ever. Both research teams have stated explicitly that test excavations are the next logical step needed to answer the research objectives.[54] The stratigraphic and depositional origin of the Kennewick Skeleton must be established conclusively. It is imperative that the Site's three-dimensional sedimentology and stratigraphy be described and that these analyses be used to reconstruct the taphonomy of the human remains. The origin, geological age, and cultural affiliation of Kennewick Man will never be known unless the Site's geology is examined thoroughly and with the most modern scientific methods available.

Phase Three studies should proceed immediately. First, the Corps' debris now covering the Site will progressively degrade the sediments' chemical and physical integrity the longer the refuse decays and tree roots penetrate deeper into the sediments. Second, concerns that even modest excavations will harm the Site must be based on scientific fact, not unfounded beliefs. The archaeological content and significance of the Kennewick Discovery Site can be readily and immediately tested by excavating as little as 15 square meters of sediments to a depth of approximately 2 to 2.5 meters. These excavations would affect less than 0.0004% of the testable area of the terrace. Concern that these "invasive" examinations will harm the Site is rendered moot by the Corps' shoreline burial activities that have irreparably damaged geological evidence at the point-of-discovery for the human remains, and in general along a 75-meter long section of the riverbank. Third, there is an immediate need to resolve the Site's geologic age conclusively by performing the appropriate amount of field and laboratory experiments. Without such testing, important questions will remain concerning Kennewick Man's geologic age.

The scientific potential of the Kennewick Site must be established by scrupulous adherence to fundamental principles of scientific investigation. The essence of modern science is unwavering dedication to the principle of repetitive data collection and its demanding reexamination by multiple scientists who are independent of one another. The process of repetitive analysis attains increasing importance if a discovery is revolutionary or groundbreaking. If each scientist examining the initial findings substantiates a scientific claim, the scientific community will accept the discovery. If a sci-

[53] Huckleberry et al. 1998, pp. 23-25.
[54] See Footnotes, Nos. 9-15.

entific discovery does not withstand reanalysis, the original data, its collection, and finally the methods and interpretations of those data must be reexamined.

The most fundamental principle of science—testing by peers— has been abrogated at the Kennewick Site. No one person or group of scientists, regardless of their institutional or governmental affiliation, should be anointed as the final, absolute bearers of truth. Scientific discoveries must pass the test of reexamination, a process that becomes increasingly necessary as the discovery becomes ever more important. At the Kennewick Site, there are no valid geological, archaeological or environmental reasons to have banned or continue to ban the types of analyses needed to understand the Site's geology. The sediment volume of the Site is enormous and testing demands are so minimal that there is no reason to fear the Site would be harmed in any meaningful sense. If the Site is studied by only a small group of investigators and if independent analyses are forbidden, the potential of the Kennewick Site and the meaning of the Kennewick Man skeleton will remain forever unknown.

It is imperative that multiple scientists test the Kennewick Site until a consensus is reached on the Site's interpretations. These tests must be conducted without outside governmental interference and the scientists involved must be fully qualified to carry out the necessary data recovery, analysis, and interpretation.

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