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## Redefining the Age of Clovis: Implications for the Peopling of the Americas

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# Redefining the Age of Clovis: Implications for the Peopling of the Americas

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## Materials and Methods

*Chemical protocols for dating bone, antler, and ivory.* AMS $^{14}C$ chemistry followed Stafford (*S1, S2*) with the following modifications. Bone, ivory or tooth dentine were physically cleaned by removing the outer 1 to 3 mm of cortex, followed by washing in acetone and methanol and drying under vacuum. Bones were broken into approximately 5-10 mm fragments and decalcified in 4°C, 0.5*N* HCl over 3 to 5 days; after washing in DI water, the decalcified collagen was extracted with 0.1% KOH at 4°C for 24 hours, then washed to neutrality with DI water. The KOH-extracted, decalcified collagen's percent pseudomorph was recorded, and then freeze dried to determine percent yield of collagen relative to modern bone. Approximately 20-50 mg of decalcified, KOH-extracted collagen were heated at 110°C in 0.02N HCl to dissolve (gelatinize) the collagen. Heating continued only until the collagen dissolved, usually 5 to 30 minutes. After filtering the gelatin solution through 0.45 μm Millex Durapore filters, the solution was freeze-dried and a percent gelatinization and yield were determined. Approximately 20-25 mg of gelatin were hydrolyzed 22 hours at 110°C in 6*N* HCl. The hydrolyzate, which contained free amino acids, fulvic acids, and insoluble inorganic and organic detritus was passed through a 2 cm long X 5 mm diameter bed of XAD-2 resin in a solid phase extraction (SPE) column attached to a 0.45 μm Millex filter. The XAD column contained 100-200 μm diameter research grade XAD-2, from Serva Biochemicals (Cat. No. 42825). The bulk resin was wetted by using acetone and washed voluminously with DI water and finally multiple washes with 1*N* HCl (distilled). Individual SPE columns were packed with the XAD-2 as slurry of resin and HCl. Each column was equilibrated with 50 ml of distilled 6*N* HCl and the washings discarded. The collagen hydrolyzate as approximately 1 to 5 ml of HCl was pipetted onto the SPE XAD column and eluted into a glass tube. Following the initial sample aliquot, the column was washed with 10 ml of 6*N* HCl that was added to the original eluate.

The XAD-purified collagen hydrolyzate was dried by passing UHP $N_2$ gas over the glass tube heated to 50°C. The dried amino acids were a viscous syrup. The dry hydrolyzate was diluted with DI water and approximately 8-10 mg of amino acids were transferred to 4 mm ID X 20 mm long quartz tubes and dried under vacuum. Approximately 200-300 mg of purified CuO wire and 20 mg Ag were added to each quartz tube. Stock CuO wire (Fisher Scientific, Cat. No. C474-500) was first combusted in crucibles at 900°C and stored in Pyrex tubes that were subsequently combusted at 570°C immediately before each use. Aesar 99.9995%, 30-60 mesh silver powder was used without additional purification. All glass pipettes, beakers, and tubes were combusted at 550°C before use. After evacuation to < 20 millitorr by vacuum pumping through a LN trap, the tubes were sealed with a $H_2/O_2$ torch. The tubes were combusted at 850°C for 2 hours and cooled from 850°C to 150°C at 30°C per hour. Following purification of the combustion products to remove water and $N_2$, approximately 1 milligram of carbon as $CO_2$ was converted into graphite by the Fe-$H_2$ method (Stafford, *et al.*, 1991). Contemporary $^{14}C$ standards included Oxalic Acid-I and ANU sucrose. Respective chemistry and combustion backgrounds were determined by using > 70ka collagen isolated from the fossil *Eschritus* (Whale) bone (*S2,S3*) and Sigma Chemical Co alanine (Sigma A-7627). Graphite targets were analyzed at the Keck Carbon Cycle AMS Facility, Earth System Science Department, University of California-Irvine.

## Text

The radiocarbon records for Clovis and Clovis-age sites are discussed below. The numbers associated with specific sites correspond to those on table S1.

1. Lange-Ferguson, South Dakota: Five radiocarbon ages were obtained from the Lange-Ferguson site in South Dakota. Two of these ages are disregarded because they were derived from unspecified organic material and unpurified mammoth bone collagen (*S4*), chemical fractions that are known to produce erroneous ages. Furthermore, the two dates have large standard deviations. Charcoal from the Clovis horizon (AA-905) (*S5*) and new ages on XAD-purified collagen (UCIAMS-11344 and 11345) are used to calculate an average date of 11,080 $\pm$ 40 $^{14}$C yr B.P. for this site.

2. Sloth Hole, Florida: One radiocarbon age on XAD-purified collagen from an ivory foreshaft was obtained from the Clovis layer at Sloth Hole, Florida (*S6*). This date, with the caveat that only one date was obtained for this horizon, appears to provide an accurate date for this site.

3. Anzick, Montana: The Anzick site in Montana is reported to be a Clovis burial and cache. At Anzick, 12 radiocarbon dates were obtained from the cranial elements of a purported Clovis infant skeleton and 2 dates on associated bone foreshafts. Collagen extracted from the foreshafts yielded an average age of 11,040 $\pm$ 35 $^{14}$C yr B.P. (*S7*). The human skeletal remains were dated during three separate research programs. The first batch of seven dates on bone comprise five chemical fractions that were considered reliable and averaged to 10,680 $\pm$ 50 $^{14}$C yr B.P. (*S2*). Later, a single purified collagen sample yielded a date of 11,550 $\pm$ 60 $^{14}$C yr B.P. (CAMS-35912). This measurement is rejected because subsequent dating of the same XAD fraction and preceding fractions from newly sampled bone did not replicate the 11,550 $^{14}$C yr B.P. result. The source of the contaminating $^{14}$C-depleted carbon is unknown. A more recent series of dates from a single cranial fragment provided four new radiocarbon ages. These fractions confirm previous date estimates for the skeleton of 10,705 $\pm$ 35 $^{14}$C yr B.P. The $^{14}$C dates on the skeleton versus the dates on the bone foreshafts suggest that the skeletal remains and Clovis artifacts may not be related and that the foreshaft ages more accurately date the site. The 10,700 year old human remains could post-date the Clovis cache, but additional research is needed to resolve this issue. A more recent, late Paleoindian or early Archaic human skeleton was also found at the site (*S7*). The association of any of the human remains with the Clovis cache is problematic because the site had been excavated accidentally with heavy machinery before the human bones and artifacts were recognized and later recovered at some distance from the actual site. Thus, the directly dated Clovis artifacts—the foreshafts—appear to accurately date the site.

4. Dent, Colorado: Nine radiocarbon ages were obtained from the Dent site, Colorado. One date (I-622) is disregarded in the calculation of the age of this site because it was derived from unpurified mammoth bone collagen (known to produce questionable ages) and it has a large standard deviation (*S8*). Six dates, which average 10,750 $\pm$ 40 $^{14}$C yr B.P., were obtained on purified mammoth bone collagen (*S2*). Two additional dates (UCIAMS-11339 and -11340) were obtained on XAD-purified mammoth bone collagen to test the earlier results and improve the standard deviation of the previous ages. These new dates average 10,990 $\pm$ 25 yr $^{14}$C yr B.P.

5. Paleo Crossing, Ohio: At the Paleo Crossing site, Ohio, ten radiocarbon dates were obtained from the horizon containing Clovis artifacts (*S9*). The initial dates for the site provided conflicting results. Careful analysis of the context of the dates revealed that the older ages were derived from the underlying deposits. Three dates that average 10,980 $\pm$ 75 yr $^{14}$C yr B.P. from charcoal derived from post molds provided the most reliable date for the site.

6. Domebo, Oklahoma: Domebo, Oklahoma, is a mammoth kill site with associated Clovis projectile points within a well defined stratigraphic sequence. Numerous radiocarbon ages were obtained from the Domebo site, Oklahoma; however, most of the radiocarbon dates are on materials either above or below the Clovis horizon (*S3*, *S10, S11, S12*). Only four dated samples came directly from the Clovis artifact bearing unit. Three dates on purified mammoth bone collagen were obtained (*S2*) and averaged 11,040 $\pm$ 255 $^{14}$C yr B.P. This is considered a reliable date for the site, but the date has a very large standard deviation. Consequently, we redated additional Domebo bone and obtained a new date of 10,960 $\pm$ 30 $^{14}$C yr B.P. (UCIAMS-11341). This sample yielded a similar date mean, but a much reduced standard deviation that agrees well with dates generated from overlying tree stumps. The final $^{14}$C date is considered an accurate date for the Domebo site.

7. Lehner, Arizona: The age of the Clovis kill at Lehner, Arizona, has been placed at 10,950 $\pm$ 40 $^{14}$C yr B.P. based on the average of twelve radiocarbon dates on charcoal; they provide accurate dating of the Clovis component (*S5*).

8. Shawnee-Minisink, Pennsylvania: At Shawnee-Minisink, Pennsylvania, nine radiocarbon ages were obtained for the Clovis horizon. Four older ages are rejected (*S13*) in favor of five recently obtained dates. The rejected ages yielded widely scattered results with large standard deviations that are of limited utility in establishing the age of this site. Five samples of carbonized Hawthorn (*Crataegus*) seeds (*S14, S15*) were obtained from Clovis hearths and date the Clovis horizon to 10,935 $\pm$ 15 $^{14}$C yr B.P.

9. Murray Springs, Arizona: At Murray Springs, Arizona, eight radiocarbon dates on charcoal provide accurate dating of the Clovis component to 10,885 $\pm$ 50 yr $^{14}$C yr B.P. (*S5*).

10. Colby, Wyoming: At Colby, Wyoming, five radiocarbon dates were obtained. Two dates on unpurified mammoth bone collagen (RL-392 and SMU-278) and on mammoth bone apatite (SMU-254) are disregarded (*S16*). These $^{14}$C dates have large standard deviations and are on chemical fractions known to produce unreliable ages. Two new dates (UCIAMS-11342 and 11343) were obtained from XAD-purified collagen obtained from mammoth bone associated with bone pile 2. These ages provide a credible average date of 10,870 $\pm$ 20 $^{14}$C yr B.P. for the Clovis activity.

11. Jake Bluff, Oklahoma: Three radiocarbon dates were obtained from the Clovis bison kill area at Jake Bluff, Oklahoma (*S17*). These are all on XAD-purified bison bone collagen. All have yielded consistent dates and are used to estimate the date of Clovis activity at this site as 10,765 $\pm$ 25 $^{14}$C yr B.P.

12. East Wenatchee, Washington: The East Wenatchee Clovis Cache, Washington, provides pertinent chronological information. At this site, traces of Glacier Peak Ash, Layer G occurred on the undersides of Clovis artifacts (*S18*). This ash has been dated to 11,125 ± 130 $^{14}$C yr B.P. (Beta-4951) (*S19*) and provides a maximum limiting date for Clovis at this site.

13. Indian Creek, Montana: At Indian Creek, Montana, a single radiocarbon date on charcoal of 10,980 ± 110 $^{14}$C yr B.P. was obtained from the earliest component with Clovis-like artifacts (*S19*). These artifacts overlie the Glacier Peak Ash (Layer G). Charcoal associated with the ash dated to 11,125 ± 130 $^{14}$C yr B.P. (Beta-4951) at the site. Folsom artifacts with younger $^{14}$C dates overlie the early horizon.

14. Lubbock Lake, Texas: At the Lubbock Lake site, Texas, two radiocarbon ages were reported from the possible Clovis horizon (*S20*). No diagnostic Clovis artifacts have been obtained *in situ* from this component of the site, but the excavators believe that cut marks and other modification of mammoth bone provide evidence for the presence of Clovis peoples. Two wood samples from the mammoth bone horizon (SMU-548 and -263) provide credible ages for this possible Clovis surface and average to 11,100 ± 60 $^{14}$C yr B.P.

15. Bonneville Estates, Nevada: A number of early hearths have been excavated in stratum 18b at Bonneville Estates Rockshelter, Nevada (*S21*). The oldest hearth has been dated to 11,010 ± 40 $^{14}$C yr B.P. (Beta-207009). Flaking debris, but no diagnostic artifacts, are associated with this hearth.

16. Kanorado, Kansas: Three radiocarbon dates on XAD-purified bone collagen were obtained from a reported Clovis horizon (no diagnostic artifacts were recovered) at the Kanorado site, Kansas (*S22*). One of these $^{14}$C dates is rejected as too young by the excavators (*S22*) and had a very large standard deviation. Averaging the remaining two dates provides a date of 10,980 ± 40 $^{14}$C yr B.P. for this component.

17. Arlington Springs, California: XAD-purified bone collagen from human remains from Arlington Springs, California, on Santa Rosa Island yielded a date of 10,960 ± 80 $^{14}$C yr B.P. (*S23*). This is considered to be an accurate age for the skeleton. A date of 11,490 ± 70 $^{14}$C yr B.P. (CAMS-17125) was obtained on XAD-purified collagen extracted from a bone of an extinct deer mouse (*Peromyscus nesodytes*) bone from the stratigraphic unit underlying the skeleton (*S23*).

18. Sheriden Cave, Ohio: At Sheriden Cave, Ohio, several bone points, a scraper, and a Clovis projectile point were recovered with the remains of late Pleistocene fauna. At this site, thirty radiocarbon dates were obtained on charcoal and bone collagen from the deposits (*S24*). Most of these dates are from underlying and overlying deposits and bracket the artifacts. The most reliable dates are those from an extensive charcoal lense that immediately underlies the artifacts within the shelter. Two dates from this unit average 10,920 ± 50 $^{14}$C yr B.P.

19. Blackwater Draw, New Mexico: At Blackwater Draw, New Mexico, five radiocarbon dates were reported from the Clovis horizon (*S25, S26*). Two ages on humates (AA-1360 and

SMU-1880) are minimum ages and do not provide an accurate age of the Clovis activity. The other three ages were obtained on carbonized plant remains and have large standard deviations. These three dates yielded an average of 11,300 ± 235 $^{14}$C yr B.P. This large standard deviation does not provide comparable chronological control.

20. Cactus Hill, Virginia: One radiocarbon age on charcoal was obtained from the Clovis layer at Cactus Hill, Virginia (*S27*). This date appears to provide a reliable date for this site; however this age provides limited chronological information because of its large standard deviation.

21. Wally's Beach, Canada: At Wally's Beach, Canada, four radiocarbon dates have been obtained on bone collagen from bison, horse, musk oxen, and caribou (*S28, S29*). These dates range from 11,350 ± 80 $^{14}$C yr B.P. (TO-8972) to 10,980 ± 80 $^{14}$C yr B.P. (TO-7691). While this site provides evidence for the butchering of horse it is unclear which, if any of the dates, related to the butchered remains. Finally, the association of Clovis artifacts with the butchered horse remains is unclear.

22. Union Pacific, Wyoming: At the Union Pacific site, Wyoming, mammoth remains are thought to be associated with Clovis artifacts; however, the mammoth-Clovis association has not been conclusively demonstrated (*S30*). Unpurified ivory collagen yielded a date of 11,280 ± 350 $^{14}$C yr B.P. (I-449) (*S5*). This date has limited use because of the questionable Clovis association with the mammoth, the likely contamination of this sample with humic acids, and its large standard deviation.

23. Aubrey, Texas: Two dates on charcoal, averaging 11,570 ± 70 $^{14}$C yr B.P., were obtained from the Clovis occupation surface at the Aubrey site, Texas (*S31*). The charcoal used to obtain these ages did not come from an archaeological feature or a discrete geological stratum. The dated charcoal was found dispersed on an eroded surface. Alluvial sediments underlying the Clovis surface have yielded radiocarbon ages on humates ranging from 12,335 ± 170 $^{14}$C yr B.P. (SMU-2478) to 14,200 ± 220 $^{14}$C yr B.P. (SMU-2236). The samples used to date the Clovis horizon may have originated from these older deposits. Further, the late Quaternary sediments at the site are derived from coal-bearing Cretaceous bedrock and large amounts of $^{14}$C-free carbon occur in these deposits. Large amounts of $^{14}$C depleted carbon occur in the late Pleistocene deposits in the form of recycled Cretaceous palynomorphs (*S32*). These represent a potential source of contamination of the disseminated solid organic matter collected from the Clovis horizon (*S32*). This geological environment could enable geologically ancient carbon to become commingled with and contaminate the samples. Finally, the precise provenience of the two dated samples from Camp B has not been reported. Interestingly, humates from Unit E1 overlying the Clovis surface in the west Pond Area yielded an age of 10,940 ± 80 $^{14}$C yr B.P. (SMU-2194) directly above the Clovis horizon. This age is well within the range of ages for Clovis reported here. This situation has raised concerns about the validity of the early ages from the site (*S30*).

24. Sheaman, Wyoming: At the Sheaman site, Wyoming, the Clovis occupation is thought to date to 11,225 ± 50 $^{14}$C yr B.P., based on the averaging of the three oldest dates from the Clovis

horizon (*S33*). However, these dates were obtained from charcoal and insoluble organic matter and not from a feature. Dispersed charcoal from the same horizon provided dates of around 10,200 $^{14}$C yr B.P. (*S33*). A series of dates on XAD-purified collagen from the Clovis horizon foreshaft, yielded an averaged date of 10,305 $\pm$ 15 $^{14}$C yr B.P. The foreshaft was previously identified as ivory, but is actually cervid bone or antler. The results of this dating cast doubt on the Clovis assignment of the Sheaman site, which may instead be Goshen or represent a mixed site with Clovis and Goshen artifacts.

## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites.

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| **Clovis sites (credible ages and Clovis diagnostics)** | | | | | | |
| 1. | Lange-Ferguson, SD | 10,670 ± 300 | I-11,710 | Organic material | S4 | Clovis – rejected |
| | | 10,730 ± 530 | I-13,104 | Mammoth bone (collagen) | S4 | Clovis – rejected (10,800 ± 530 $^{14}$C yr B.P. with δ $^{13}$C correction) |
| | | 11,140 ± 140 | AA-905 | Charcoal | S5 | Clovis |
| | | 10,710 ± 130 | UCIAMS-11344 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis |
| | | 11,110 ± 40 | UCIAMS-11345 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis |
| | AVERAGE | 11,080 ± 40 | | | | Average of three ages (AA-905, UCIAMS-11344 and 11345) |
| 2. | Sloth Hole, FL | 11,050 ± 50 | SL-2850 | Proboscidean Ivory (XAD collagen) | S6 | Clovis – ivory haft element |
| 3. | Anzick, MT | 8,690 ± 310 | AA-313A | Human bone (HCl insoluble collagen) | S2 | Clovis – rejected |
| | | 10,500 ± 400 | AA-313B | Human bone collagen (untreated gelatin) | S2 | Clovis – rejected |
| | | 10,240 ± 120 | AA-2978 | Human bone collagen (aspartic acid from hydrolysed gelatin) | S2 | Clovis ? |
| | | 10,820 ± 100 | AA-2979 | Human bone collagen (glutamic acid from hydrolysed gelatin) | S2 | Clovis ? |
| | | 10,710 ± 100 | AA-2980 | Human bone collagen (hydroxyproline from hydrolysed gelatin) | S2 | Clovis ? |
| | | 10,940 ± 90 | AA-2981 | Human bone collagen (glycine from hydrolysed gelatin) | S2 | Clovis ? |
| | | 10,370 ± 130 | AA-2982 | Human bone collagen (alanine from hydrolysed gelatin) | S2 | Clovis ? (Average of AA-2978, 2979, 2980, 2981, and 2982: 10,680 ± 50 $^{14}$C yr B.P.) |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| | | 11,550 ± 60 | CAMS-35912 | Human bone collagen (XAD gelatin) | This report | Clovis ? fraction from archived vial of gelatin – rejected |
| | | 10,580 ± 35 | CAMS-80535 | Human bone (HCl decalcified untreated collagen) | This report | Clovis ? – rejected |
| | | 10,525 ± 35 | CAMS-80536 | Human bone (KOH extracted collagen) | This report | Clovis ? – rejected |
| | | 10,610 ± 30 | CAMS-80537 | Human bone collagen (gelatin) | This report | Clovis ? – rejected |
| | | 10,705 ± 35 | CAMS-80538 | Human bone collagen (XAD-KOH-gelatin) | This report | Clovis ? – most reliable age |
| | | 11,040 ± 60 | Beta-163832 | Bone (alkali collagen) | S7 | Clovis foreshaft |
| | | 11,040 ± 40 | Beta-168967 | Bone (alkali collagen) | S7 | Clovis foreshaft |
| | AVERAGE | 11,040 ± 35 | | | | Average of two foreshaft ages (Beta–163832 and 168967) |
| 4. | Dent, CO | 11,200 ± 500 | I-622 | Mammoth bone (collagen) | S8 | Clovis – rejected |
| | | 10,980 ± 90 | AA-2941 | Mammoth bone collagen (XAD hydrolysate) | S2 | Clovis |
| | | 10,660 ± 170 | AA-2942 | Mammoth bone collagen (aspartic acid) | S2 | Clovis |
| | | 10,800 ± 110 | AA-2943 | Mammoth bone collagen (glutamic acid) | S2 | Clovis |
| | | 10,600 ± 90 | AA-2945 | Mammoth bone collagen (hydroxyproline) | S2 | Clovis |
| | | 10,710 ± 90 | AA-2946 | Mammoth bone collagen (glycine) | S2 | Clovis (Average of A-2941, 2942, 2943, 2945, 2946, and 2947: 10,750 ± 40 $^{14}$C yr B.P.) |
| | | 10,670 ± 120 | AA-2947 | Mammoth bone collagen (alanine) | S2 | Clovis |
| | | 11,065 ± 35 | UCIAMS-11339 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis |
| | | 10,940 ± 30 | UCIAMS-11340 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis |
| | AVERAGE | 10,990 ± 25 | | | | Average of two ages (UCIAMS 11339 and 11340) |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| 5. | Paleo Crossing, OH | 12,250 ± 100 | AA-8250 | Charcoal | S9 | From post mold – rejected |
| | | 10,800 ± 185 | AA-8250-D | Charcoal | S9 | From post mold |
| | | 10,980 ± 110 | AA-8250-E | Charcoal | S9 | From post mold |
| | | 11,060 ± 120 | AA-8250-C | Charcoal | S9 | From post mold |
| | | 12,000 ± 110 | AA-8250-B | Charcoal | S9 | From post mold – rejected |
| | | 12,175 ± 115 | AA-8250-F | Charcoal | S9 | From post mold – rejected |
| | | 13,100 ± 100 | AA-8251 | Organic fragments | S9 | Cylindrical pit containing Clovis point base – side wall – rejected |
| | | 9230 ± 80 | AA-8252 | Charcoal | S9 | Above cylindrical pit |
| | | 12,900 ± 110 | AA-19131A | Charcoal | S9 | Matrix into which post holes were dug – natural sediments |
| | | 11,675 ± 90 | AA-10131B | Humates | S9 | Matrix into which post holes were dug – natural sediments |
| | AVERAGE | 10,980 ± 75 | | | | Average of three ages (AA-8250-D, 8250-E, and 8250-C) |
| 6. | Domebo, OK | 4952 ± 304 | TBN-311 | Untreated mammoth tusk | S10 | Rejected |
| | | 11,045 ± 647 | SMU-695 | Elm *(Ulnus)* wood | S10 | Stump above Clovis – rejected |
| | | 11,220 ± 500 | SI-172 | Mammoth bone (collagen) | S10 | Rejected |
| | | 11,200 ± 600 | SI-175 | Mammoth bone (collagen) | S10 | Rejected |
| | | 9400 ± 300 | OX-56 | Humic acids | S10 | Sediment sample – rejected |
| | | 10,123 ± 280 | SM-610 | Lignitic wood | S10 | Above Clovis – rejected |
| | | 10,980 ± 70 | Beta-24212 | Elm *(Ulnus)* wood | S11 | Above Clovis |
| | | 11,490 ± 450 | AA-823 | Elm *(Ulnus)* wood | S3 | Above Clovis |
| | | 11,480 ± 450 | AA-825 | Mammoth bone (XAD purified collagen) | S3 | Clovis |
| | | 10,860 ± 450 | AA-811 | Mammoth bone (proline and hydroxyproline) | S3 | Clovis |
| | | 10,810 ± 420 | AA-805 | Mammoth bone (XAD hydrolysate) | S3 | Clovis (Average of three bone ages: 11,040 ± 255 $^{14}$C yr B.P.) |
| | | 10,815 ± 85 | AA-12536 | Elm (*Ulnus*) wood | S12 | Above Clovis (rooted tree stump) |
| | | 11,090 ± 110 | AA-12534 | Bulk organic sand | S12 | Above Clovis |
| | | 11,010 ± 85 | AA-12533 | Elm *(Ulnus)* wood | S12 | Above Clovis |
| | | 10,845 ± 90 | AA-13028 | Humates | S12 | Above Clovis (humates from wood AA-12533) |
| | | 12,350 ± 100 | AA-13026 | Bulk organics and sediment | S12 | Below Clovis |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| | | 10,960 ± 30 | UCIAMS-11341 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis |
| 7. | Lehner, AZ | 10,770 ± 140 | SMU-168 | Charcoal | S5 | Clovis |
| | | 10,940 ± 100 | A-378 | Charcoal | S5 | Clovis |
| | | 11,080 ± 200 | SMU-181 | Charcoal | S5 | Clovis |
| | | 10,950 ± 110 | SMU-194 | Charcoal | S5 | Clovis |
| | | 10,860 ± 280 | SMU-164 | Charcoal | S5 | Clovis |
| | | 10,950 ± 90 | SMU-290 | Charcoal | S5 | Clovis |
| | | 11,080 ± 230 | SMU-196 | Charcoal | S5 | Clovis |
| | | 10,620 ± 300 | SMU-347 | Charcoal | S5 | Clovis |
| | | 10,700 ± 150 | SMU-297 | Charcoal | S5 | Clovis |
| | | 10,710 ± 90 | SMU-340 | Charcoal | S5 | Clovis |
| | | 11,170 ± 200 | SMU-264 | Charcoal | S5 | Clovis |
| | | 11,470 ± 110 | SMU-308 | Charcoal | S5 | Clovis |
| | AVERAGE | 10,950 ± 40 | | | | Average of all 12 ages |
| 8. | Shawnee-Minisink, PA | 10,590 ± 300 | W-2994 | Charcoal and charred seeds | S13 | Clovis – rejected |
| | | 10,750 ± 600 | W-3134 | Charcoal | S13 | Clovis hearth – rejected |
| | | 9,310 ± 1000 | W-3388 | Charcoal-stained soil matrix | S13 | Clovis fluted point – rejected |
| | | 11,050 ± 1000 | W-3391 | Charcoal-stained soil matrix | S13 | Clovis fluted point – rejected |
| | | 10,940 ± 90 | Beta-101935 | Carbonized Hawthorn seed (*Crataegus*) | S14 | Clovis hearth |
| | | 10,900 ± 40 | Beta-127162 | Carbonized Hawthorn seed (*Crataegus*) | S14 | Clovis hearth |
| | | 10,820 ± 50 | Beta-203865 | Carbonized Hawthorn seed (*Crataegus*) | S15 | Clovis hearth |
| | | 10,915 ± 25 | UCIAMS-24865 | Carbonized Hawthorn seed (*Crataegus*) | This report | Clovis hearth |
| | | 11,020 ± 30 | UCIAMS-24866 | Carbonized Hawthorn seed (*Crataegus*) | This report | Clovis hearth |
| | AVERAGE | 10,935 ± 15 | | | | Average of five ages (Beta-101935, 127162, and 203865, UCIAMS-24865 and 24866) |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| 9. | Murray Springs, AZ | 11,190 ± 180 | SMU-18 | Charcoal | S5 | Clovis |
| | | 11,150 ± 450 | A-805 | Charcoal | S5 | Clovis |
| | | 11,080 ± 180 | TX-1413 | Charcoal | S5 | Clovis |
| | | 10,930 ± 170 | TX-1462 | Charcoal | S5 | Clovis |
| | | 10,890 ± 180 | SMU-27 | Charcoal | S5 | Clovis |
| | | 10,840 ± 70 | SMU-41 | Charcoal | S5 | Clovis |
| | | 10,840 ± 140 | SMU-42 | Charcoal | S5 | Clovis |
| | | 10,710 ± 160 | TX-1459 | Charcoal | S5 | Clovis |
| | AVERAGE | 10,885 ± 50 | | | | Average of all eight ages |
| 10. | Colby, WY | 11,200 ± 220 | RL-392 | Mammoth bone (collagen) | S16 | Clovis – Bone Pile 2 – rejected |
| | | 10,864 ± 141 | SMU-254 | Mammoth bone (bone apatite carbonate) | S16 | Clovis – Bone Pile 2 – rejected |
| | | 8719 ± 392 | SMU-278 | Mammoth bone (collagen) | S16 | Clovis – rejected |
| | | 10,790 ± 30 | UCIAMS-11342 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis – Bone Pile 2 |
| | | 10,950 ± 30 | UCIAMS-11343 | Mammoth bone (XAD gelatin KOH collagen) | This report | Clovis – Bone Pile 2 |
| | AVERAGE | 10,870 ± 20 | | | | Average of two ages (UCIAMS 11342 and 11343) |
| 11. | Jake Bluff, OK | 10,750 ± 40 | CAMS-79940 | Bison bone (XAD-purified collagen) | S17 | Clovis |
| | | 10,840 ± 45 | CAMS-90968 | Bison bone (XAD-purified collagen) | S17 | Clovis |
| | | 10,700 ± 45 | CAMS-90969 | Bison bone (XAD-purified collagen) | S17 | Clovis |
| | AVERAGE | 10,765 ± 25 | | | | Average of three ages (CAMS-79940, 90968 and 90969) |
| **Clovis sites (indirectly dated and Clovis diagnostics)** | | | | | | |
| 12. | East Wenatchee, WA | <11,125 ± 130 | Beta-4951 | Charcoal | S18, S19 | Date for Glacier Peak Ash G from Indian Creek, Montana. Clovis artifacts post-date Glacier Peak Ash G |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| **Clovis-age sites (credible ages, but no Clovis diagnostics)** | | | | | | |
| 13. | Indian Creek, MT | 10,980 ± 110 | Beta-4619 | Charcoal | S19 | Artifacts overlie Glacier Peak Ash Layer G dated to 11,125 ± 130 $^{14}$C yr B.P. (Beta-4951) |
| 14. | Lubbock Lake, TX | 11,100 ± 100 | SMU-548 | Wood | S20 | Stratum 1C – Clovis? |
| | | 11,100 ± 80 | SMU-263 | Wood | S20 | Stratum 1C – Clovis? |
| | AVERAGE | 11,100 ± 60 | | | | Average of two ages (SMU-548 and 263) |
| 15. | Bonneville Estates, NV | 11,010 ± 40 | Beta-207009 | Hearth charcoal | S21 | Stratum 18b – hearth with artifacts |
| 16. | Kanorado, KS | 10,150 ± 500 | CAMS-112740 | Bone (XAD collagen) | S22 | Clovis? – 14SN101 – rejected |
| | | 10,950 ± 60 | CAMS-112741 | Bone (XAD collagen) | S22 | Clovis? – 14SN105 |
| | | 11,005 ± 50 | CAMS-112742 | Bone (XAD collagen) | S22 | Clovis? – 14SN106 |
| | AVERAGE | 10,980 ± 40 | | | | Average of two ages (CAMS-112741 and 112742) |
| 17. | Arlington Springs, CA | 10,960 ± 80 | CAMS-16810 | Bone (XAD collagen) | S23 | Human skeleton |
| **Problematic Clovis and Clovis-age sites** | | | | | | |
| 18. | Sheriden Cave, OH | 10,550 ± 70 | Beta-117604 | Charcoal | S24 | Above artifacts |
| | | 10,570 ± 70 | Beta-117605 | Charcoal | S24 | Above artifacts |
| | | 10,600 ± 60 | Beta-117603 | Charcoal | S24 | Above artifacts |
| | | 10,620 ± 70 | Beta-117606 | Charcoal | S24 | Above artifacts |
| | | 10,680 ± 80 | AA-21710 | Charcoal | S24 | Above artifacts |
| | | 10,840 ± 80 | Beta-127909 | Charcoal | S24 | Below artifacts |
| | | 10,960 ± 60 | Beta-127910 | Charcoal | S24 | Below artifacts |
| | AVERAGE (above artifacts) | 10,600 ± 30 | | | | Average of five ages (Beta-117604, 117605, 117603, 117606 and AA-21710) |
| | AVERAGE (below artifacts) | 10,920 ± 50 | | | | Average of two ages (Beta-127909 and 127910) |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| 19. | Blackwater Draw, NM | 11,170 ± 360 | A-481 | Carbonized plants "organic laminae" | S25 | Clovis (C0) |
| | | 11,040 ± 500 | A-490 | Carbonized plants "organic laminae" | S25 | Clovis (C1) |
| | | 11,630 ± 400 | A-491 | Carbonized plants "organic laminae" | S25 | Clovis (C1) (Average of A-481, A-490, and A-491: 11,230 ± 235 $^{14}$C yr B.P.) |
| | | 10,580 ± 100 | AA-1360 | Humates | S25 | Clovis (C) – rejected |
| | | 10,780 ± 180 | SMU-1880 | Humates | S26 | Clovis (humates from sediment around mammoth bones in plaster jacket) – rejected |
| | AVERAGE | 11,300 ± 235 | | | | Average of three ages (A-481, 490, and 491) |
| 20. | Cactus Hill, VA | 10,920 ± 250 | Beta-81589 | Charcoal (southern hard pine) | S27 | Clovis hearth (lower half) |
| | | 9790 ± 200 | Beta-80181 | Charcoal (hard pine, oak, hickory) | S27 | Clovis hearth (upper half) – rejected |
| | | 9155 ± 80 | AA-15023 | Charcoal (pine, oak, hickory) | S27 | Clovis – single layer of charcoal – rejected |
| | | 6905 ± 55 | AA-15026 | Charcoal (pine, oak, hickory) | S27 | Clovis – single layer of charcoal – rejected |
| | | 6580 ± 55 | AA-15025 | Charcoal (pine, oak, hickory) | S27 | Clovis – single layer of charcoal – rejected |
| | | 5285 ± 50 | AA-15024 | Charcoal (pine, oak, hickory) | S27 | Clovis – single layer of charcoal – rejected |
| 21. | Wally's Beach, Canada | 11,130 ± 90 | TO-7693 | Bison bone (collagen) | S28 | Clovis association? |
| | | 11,330 ± 70 | TO-7696 | Horse bone (collagen) | S28 | Clovis association? |
| | | 10,980 ± 80 | TO-7691 | Musk oxen bone (collagen) | S28 | Clovis association? |
| | | 11,350 ± 80 | TO-8972 | Caribou bone (collagen) | S28 | Clovis association? |
| 22. | Union Pacific, WY | 11,280 ± 350 | I-449 | Proboscidean tusk organics (approximately collagen) | S5 | Date likely associated with Clovis |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| 23. | Aubrey, TX | 11,540 ± 110 | AA-5271 | Charcoal | S31 | Clovis occupation surface Camp B |
| | | 11,590 ± 90 | AA-5274 | Charcoal | S31 | Clovis occupation surface Camp B |
| | AVERAGE | 11,570 ± 70 | | | | Average of both ages |
| 24. | Sheaman, WY | 9086 ± 70 | AA-42532 | Dispersed charcoal | S33 | Above cultural horizon |
| | | 10,251 ± 72 | AA-42533 | Dispersed charcoal | S33 | Cultural horizon |
| | | 10,026 ± 86 | AA-42534 | Humic acids from AA-42533 | S33 | Cultural horizon |
| | | 1820 ± 170 | AA-42535 | Charcoal | S33 | Below cultural horizon |
| | | 10,153 ± 90 | AA-42979 | Charcoal | S33 | Below cultural horizon |
| | | 11,379 ± 70 | AA-40991 | Charcoal and insoluble organic matter | S33 | Cultural horizon |
| | | 11,810 ± 300 | AA-40988 | Charcoal and insoluble organic matter | S33 | Cultural horizon |
| | | 11,040 ± 70 | AA-40989 | Charcoal and insoluble organic matter | S33 | Cultural horizon |
| | | 10,328 ± 65 | AA-40990 | Humic acids | S33 | Cultural horizon (AA-40991, AA-40988, AA-40989, and AA-40990 from same sample) |
| | | 10,370 ± 30 | UCIAMS-11675 | Bone (XAD gelatin KOH collagen) | This report | Cultural horizon – antler/bone foreshaft |
| | | 10,275 ± 25 | UCIAMS-21992 | Bone (KOH collagen) | This report | Cultural horizon – antler/bone foreshaft |
| | | 10,295 ± 20 | UCIAMS-21993 | Bone (XAD gelatin KOH collagen) | This report | Cultural horizon – antler/bone foreshaft |
| | AVERAGE | 10,305 ± 15 | | | | Average of three ages (UCIAMS-11675, 21992 and 21993) |
| **Ages from other early sites** | | | | | | |
| 25. | Mill Iron, MT | 11,010 ± 140 | Beta-16178 | Charcoal | S5 | Goshen |
| | | 10,760 ± 130 | Beta-20110 | Charcoal | S5 | Goshen |
| | | 10,770 ± 85 | AA-3669 | Charcoal | S5 | Goshen |
| | | 10,990 ± 170 | NZA-623 | Charcoal | S5 | Goshen |
| | AVERAGE | 10,840 ± 60 | | | | Average of all four ages |

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## Table S1. Radiocarbon Dates from Clovis and Clovis-Age Sites

| Site | | Date $^{14}$C yr B.P. | Laboratory Number | Material Dated | Reference | Remarks |
|---|---|---|---|---|---|---|
| 26. | Hell Gap, WY | 10,955 ± 135 | AA-14434 | Charcoal | S34 | Goshen |
| 27. | Cerro Tres Tetas, Argentina | 10,850 ± 150 | LP-781 | Charcoal | S35 | Hearth – Lower Unit 5 |
| | | 10,853 ± 70 | AA-39366 | Charcoal | S35 | Hearth – Lower Unit 5 |
| | | 10,915 ± 65 | OXA-9244 | Charcoal | S35 | Hearth – Lower Unit 5 |
| | | 11,015 ± 66 | AA-39368 | Charcoal | S35 | Hearth – Lower Unit 5 |
| | | 11,100 ± 150 | AA-22233 | Charcoal | S35 | Hearth – Lower Unit 5 (same as LP-781) |
| | | 11,560 ± 140 | LP-525 | Charcoal | S35 | Rejected |
| | AVERAGE | 10,935 ± 35 | | | | Average of five ages (LP-781, AA-39366, OXA-9244, AA-39368, 22233 and AA-11340) |
| 28. | Cueva Casa del Minero, Argentina | 10,967 ± 55 | AA-37208 | Charcoal | S36 | Hearth – Unit 4 |
| | | 10,999 ± 55 | AA-37207 | Charcoal | S36 | Hearth – Unit 4 |
| | AVERAGE | 10,985 ± 40 | | | | Average of both ages |
| 29. | Piedra Museo, Argentina | 10,925 ± 65 | OXA-8528 | Bone collagen | S37 | Unit 6 – bottom |
| | | 11,000 ± 65 | AA-27950 | Charcoal | S37 | Unit 6 – bottom |
| | | 12,890 ± 90 | AA-20125 | Charcoal | S37 | Unit 6 – bottom – rejected |
| | AVERAGE | 10,960 ± 45 | | | | Average of two ages (OXA-8528 and AA-27950) |
| 30. | Fell's Cave, Chile | 10,080 ± 160 | I-5146 | Charcoal | S38 | Hearth – Level 18 – Fishtail |
| | | 10,720 ± 300 | W-915 | Charcoal | S38 | Hearth – Level 19 – Fishtail |
| | | 11,000 ± 170 | I-3988 | Charcoal | S38 | Hearth – Level 20 – Fishtail |

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