3. G. Humason, *Animal Tissue Techniques* (Freeman, San Francisco, 1972), pp. 289–290.
4. C. Y. Lai, in *Methods in Enzymology*, C. H. W. Hirs and S. N. Timasheff, Eds. (Academic Press, New York, 1977), pp. 241–243.
5. Sigma Chemical Company, *Tech. Bull. 540* (1980). Total protein from residue sample IgSk 8:84 was 59 μg/dl.
6. E. Nelson, personal communication. Independent total protein determined for an aloquot of the residue sample IgSk 8:84 was 55 μg/dl.
7. T. McMeeking, M. Groves, N. Hipp, in *Amino Acids and Serum Proteins*, J. Stekol, Ed. (American Chemical Society, Washington, D.C., 1964), pp. 54–66.
8. W. Andrew, *Comparative Hematology* (Grune & Stratton, New York, 1965).
9. C. Best, *The Physiological Basis of Medical Practice* (Williams and Wilkins, Baltimore, 1961), pp. 57–60.
10. *Chemstrip 5*, Boehringer Mannheim, Mannheim, Germany.
11. F. Cotton and F. Wilkinson, *Basic Inorganic Chemistry* (Wiley, New York, 1976), pp. 551–558.
12. J. Holum, *Introduction to Organic and Biological Chemistry* (Wiley, New York, 1969).
13. F. Bruier, *Am. Antiq.* **41**, 478 (1976).
14. R. Czok and T. Bucher, *Adv. Protein Chem.* **15**, 323 (1960).
15. M. Dixon and E. Webb, *ibid.* **16**, 197 (1961).
16. R. Washino, *Identification of Host Blood Meals in Arthropods* (U.S. Army Medical Research and Development Command, Washington, D.C., 1977). The artifact is air-dried and brushed clean with a soft brush; 80 μl of distilled and deionized water is applied to the surface, and, after 60 minutes in a humid chamber, 50 μl is transferred to a standard microscope slide; 20 μl of a 3*M* monobasic and dibasic sodium phosphate buffer, *p*H 6.4 at 22°C, is added; after 5 minutes, 10 μl of 0.125*M* ammonium oxalate solution, *p*H 6.5 at 22°C, is added; after warming to 35°C and allowing to cool to 22°C, the drop is cover slipped and examined at magnifications of 200 to 500 diameters; the cover slip is sealed within 1 hour. Crystal development, depending upon the species, can take between 20 minutes and 24 hours.
17. Two separate blind tests were carried out with positive identification in nine out of nine and five out of five cases [R. Washino and J. Else, *Am. J. Trop. Med. Hyg.* **21**, 120 (1972)].
18. R. Dickerson and I. Geis, *The Structure and Action of Proteins* (Harper and Row, New York, 1969), pp. 51–62; M. F. Perutz, *Science* **140**, 863 (1963).
19. E. Reichert and A. Brown, *The Crystallography of Hemoglobins* (Publication 16, Carnegie Institution of Washington, Washington, D.C., 1909), pp. 141–320.
20. Research Plus Laboratories, Inc., Bayonne, N.J.
21. C. Templis, *J. Med. Entomol.* **11**, 635 (1975).
22. H. Schultze and J. Heremans, *The Molecular Biology of Human Proteins* (Elsevier, Amsterdam, 1966), pp. 41–46; W. Ramsay, in *Haemoglobin*, F. Roughton and J. Kendrew, Eds. (Butterworth, London, 1949), pp. 240–241.
23. M. Perutz, *Sci. Am.* **211**, 65 (November 1964).
24. H. Jannasch, in *Environmental Biogeochemistry and Geomicrobiology*, W. Krumbein, Ed. (Ann Arbor Science, Ann Arbor, Mich., 1978), pp. 17–24. Bacteria and saprophytic spores may be incorporated in the blood residues and be confused with red blood cells, as was the case for P. Lewin and E. Cutz [*Br. J. Dermatol.* **94**, 573 (1976)]. I have noted no such contamination in the samples I examined, for, unlike the case for mummification, the drying and fixing of blood residues on tool surfaces is rapid, allowing little time for colonization and growth within the deposit.
25. M. Allison, A. Hossanni, J. Munizaga, R. Fung, *Am. J. Phys. Anthropol.* **49**, 139 (1978); R. Barraco, *ibid.* **48**, 493 (1978); J. Riddle, K.-L. Ho, J. Chason, R. Schwyn, *Micron* **7**, 237 (1976); E. M. Prager, A. C. Wilson, J. M. Lowenstein, V. M. Sarich, *Science* **209**, 287 (1980).
26. A. Weiss, in *Organic Geochemistry*, G. Eglinton and M. Murphy, Eds. (Springer, New York, 1969), pp. 737–775.
27. I thank M. Florian, R. Washino, P. Robinson, E. Nelson, R. Olafson, R. G. V. Hancock, D. Buie, and J. Hill for encouragement, discussion, and technical guidance and A. McMurdo and B. Rimmer for research assistance. Supported by grants from the Friends of the British Columbia Provincial Museum.

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Middle Holocene Age of the Sunnyvale Human Skeleton

Abstract. *A morphologically modern human skeleton from Sunnyvale, California, previously dated by aspartic acid racemization to be approximately 70,000 years old and by uranium series isotopic ratios to be 8300 and 9000 years old, appears to be younger when dated by the carbon-14 method. Four carbon-14 determinations made by both decay and direct counting on three organic fractions of postcranial bone support a middle Holocene age assignment for the skeleton, probably in the range of 3500 to 5000 carbon-14 years before the present. This dating evidence is consistent with the geologic, archeological, and anthropometric relationships of the burial as well as previously determined carbon-14 determinations on associated materials.*

Bada and Helfman in 1975 (*1*) assigned an age of approximately 70,000 years, based on aspartic acid racemization measurements, to a morphologically fully modern, nearly complete female human skeleton excavated in 1972 from the Sunnyvale East Drainage Channel, located in the southern portion of San Francisco Bay, California. If correctly dated, the Sunnyvale hominid would be one of the oldest directly dated *Homo sapiens sapiens* skeletons in the world. It would predate by approximately 30,000 years the generally accepted age for the earliest appearance of anatomically modern human populations in the Old World (*2, 3*). Several investigators have accepted the essential accuracy of the 70,000 years age assignment for the Sunnyvale skeleton (*4–6*) and have offered it as evidence to argue against the view that the earliest human populations reached the New World relatively late in the Pleistocene (*7–9*).

The validity of the age derived from aspartic acid racemization dating was challenged by Gerow, Lajoie, and Peterson on geologic, archeological, and anthropometric grounds supported by several ^{14}C determinations (*9, 10*). The skeleton had been interred in a well-defined grave pit, 53 cm in diameter, excavated to a depth of 2.7 m below the present ground surface [figure 6 in (*10*)]. The pit had been excavated into a buried soil of terminal Pleistocene age that contained Rancholabrean fauna and freshwater shells which yielded two ^{14}C determinations of 10,110 ± 260 (I-8084) and 10,430 ± 150 (I-6476) ^{14}C years before present (B.P.). An artifact fashioned from antler (possibly elk) was recovered from a feature (a possible trash pit) that is 400 m north of the burial locality and intrudes into sediments similar to those surrounding the burial pit. Charcoal directly associated with the antler artifact yielded an age of 4460 ± 95 ^{14}C years B.P. (I-6977). The antler tool and human burial exhibit similar aspartic acid racemization measurements, and neither show evidence of heating by fire. Physiographically the location of the burial site resembles a common late Holocene prehistoric settlement pattern found along the shores of the southern portion of the San Francisco Bay (*11*). Finally, the reconstructed Sunnyvale female is statistically indistinguishable in 32 standard measurements and indices from a selected local population of female skeletons dated by radiocarbon and cultural associations to between 400 and 1600 ^{14}C years ago [table 5 in (*10*)]. On the basis of these lines of evidence, it has been argued that the age of the Sunnyvale skeleton was less than 10,000 years (Holocene) and possibly less than 4500 ^{14}C years (*9, 10*). Ages of 8300 and 9000 years old were obtained from uranium series analyses of bone samples from the Sunnyvale skeleton by Bischoff and Rosenbauer (*12*). Bada and Finkel (*13*) suggested that the uranium values should be considered minimum estimates, but Bischoff and Rosenbauer (*14*) said that the validity of the various age estimates should be tested by comparison with an independent radiometric technique such as ^{14}C.

We have obtained both decay and direct counting ^{14}C determinations on three organic fractions of postcranial bone from the Sunnyvale skeleton. To eliminate the inorganic carbonate fraction, the Sunnyvale bone, after mechanical and ultrasonic cleaning, was ground to pass through 0.104-mm mesh and

Table 1. Radiocarbon counting data for calibration samples.

Sample	R^* expected	R^* measured
ANU sucrose	1.000	1.003
ANU sucrose		±.006
New NBS oxalic acid†	1.369	1.395
Tree ring, A.D. 1890	±.010	±.017
Tree ring, 5050 B.C.	0.48‡	0.50
Tree ring, A.D. 1890		±.03
Tree ring, 1000 B.C.	0.71‡	0.74
Tree ring, A.D. 1890		±.04

*R = the expected and measured ratios of the $^{14}C/^{13}C$ values for the indicated materials. †National Bureau of Standards reference material RM-49. ‡Based on data from Klein *et al.* (*21*).

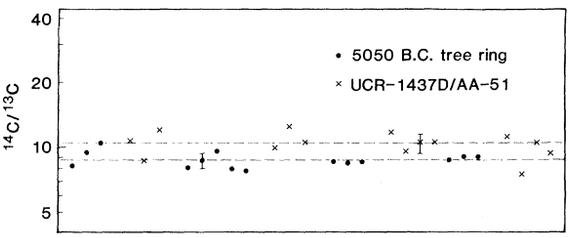

Fig. 1. Measurements of $^{14}C/^{13}C$ ratios in a sample of Sunnyvale hominid bone (UCR-1437D/AA-51) and in 5050 B.C. wood. Each data point represents a 480-second collection of ^{13}C and ^{14}C counts. The total period of the experiment was 4 hours. The error bars indicate the statistical error of the individual measurements. The dotted lines are averages of the measurements.

treated with 0.8*N* HCl until the *p*H was less than 2. This material was then centrifuged and the soluble fraction evaporated to dryness. Decay counting of this fraction (UCR-1437A, total acid soluble organics) could be accomplished by CO_2 gas proportional counting with the equivalent of 250 mg of carbon (*15*). The acid-insoluble fraction was treated with 0.5 percent carbonate ion-free NaOH for 20 hours at room temperature. This material was centrifuged and the NaOH-soluble fraction neutralized to *p*H 7 and evaporated to dryness (UCR-1437B, total base-soluble organics). The NaOH-insoluble fraction was brought to and maintained at *p*H 3 while being heated at 90°C for 8 hours with continuous stirring to convert this fraction to gelatin. It was then filtered, washed with distilled water, and oven dried at 105°C (UCR-1437D, total insoluble organics after gelatin conversion with base soluble fraction removed). Details of the pretreatment of bone samples for ^{14}C analysis have been reviewed elsewhere (*16–18*).

The CO_2 yields from the combustion of UCR-1437B and UCR-1437D were insufficient for decay counting at the UCR laboratory. With the equivalent of about 2 mg of carbon in both cases, the ^{14}C content of these samples was measured by tandem accelerator mass spectrometry (*19*). Carbon dioxide from each of the three chemical fractions was reduced to elemental carbon, converted to Al_4C_3 powder, packed into a sample holder and mounted in the ion source of the accelerator. Ions are sputtered from the target and directed to a magnet which selects $^{14}C^-$ ions and CH_n molecules with mass = 14 atomic mass units. We have seen no evidence for $^{14}N^-$ ions. The ions passed by the injection magnet are accelerated to the terminal of the tandem accelerator, where they are stripped of several electrons and then accelerated back to ground potential. After leaving the accelerator, they pass through an electrostatic deflector which selects a particular kinetic energy and a charge state +3e. Essentially no molecules survive the stripping process in this charge state, and molecular fragments are eliminated by the deflector. Two magnets at the high-energy end of the system select ions with a particular value of momentum/charge and greatly reduce background. The ions then enter a $\Delta E - E$ detector, which counts ^{14}C and discriminates against ^{14}N, ^{13}C, and ^{12}C background counts.

After the ^{14}C rate has been determined, the injection magnet is switched to pass $M = 13$ amu and ^{13}C ions are integrated in a Faraday cup at the high-energy end of the accelerator. In practice, ^{14}C and ^{13}C beams are cycled through the system about once per minute. Finally, a standard target of known isotopic content is inserted into the ion source, ^{14}C and ^{13}C rates are measured, and the ratio $R = (^{14}C/^{13}C)_{sample}/(^{14}C/^{13}C)_{standard}$ is determined. Unknown and standard targets are cycled several times per hour. This procedure has been tested on several samples with known $^{14}C/^{13}C$ ratios (Table 1).

The standard samples used for the Sunnyvale measurements were made from wood of 5050 B.C. tree rings (*20*), and values of $^{14}C/^{13}C$ obtained from a series of measurements on UCR-1437D/AA-51 and on the standard were plotted (Fig. 1). The measurements indicate that this fraction of the Sunnyvale bone sample is slightly younger than the 5050 B.C. wood. From the data illustrated in Fig. 1, we obtain a value of *R* [(UCR-1437D/AA-51)/(5050 B.C. tree ring)] = 1.19 ± 0.05. The error quoted on this ratio is the standard deviation of the average of the 14 measurements of the ratio. It is approximately equal to the statistical uncertainty in the measurement. The errors quoted for all accelerator measurements in Table 2 were deduced in the same manner. According to Klein *et al.* (*21*), the radiocarbon age of 5050 B.C. wood is 6050 years B.P. Using this age, together with the measured value of *R* and the Libby half-life of ^{14}C, $t_{1/2} = 5568$ years, we calculate an age for UCR-1437D/AA-51 of 4650 ± 400 ^{14}C years B.P. Results of accelerator measurements on samples

Table 2. Radiocarbon counting data for samples from Sunnyvale site locality, southern San Francisco Bay, California.

Laboratory number	Sample	Counting method	*R** measured	Radiocarbon age (^{14}C years B.P., $t_{1/2}$ = 5568 years)
		Burial pit		
UCR-1437A	Sunnyvale hominid bone, total HCl-soluble organic fraction, 2.7-m depth	Decay		4,390 ± 150†
UCR-1437A/AA-50	Sunnyvale hominid bone, total HCl-soluble organic fraction, 2.7-m depth	Direct	1.36 ± 0.10	3,600 ± 600
UCR-1437B/AA-52	Sunnyvale hominid bone, total NaOH-soluble organic fraction, 2.7-m depth	Direct	1.16 ± 0.05	4,850 ± 400
UCR-1437D/AA-51	Sunnyvale hominid bone, total HCl-insoluble organics after gelatin conversion with base soluble fraction removed, 2.7-m depth	Direct	1.19 ± 0.05	4,650 ± 400
		Adjacent to burial pit		
I-8084	Dispersed freshwater shell (*Physa* sp. and *Limnea* sp.), 2.5-m depth	Decay		10,110 ± 260
I-6476	Dispersed freshwater shell (*Physa* sp. and *Limnea* sp.), 2.5-m depth	Decay		10,430 ± 150
		Trash pit (?)		
I-6977	Charcoal, 2.0-m depth	Decay		4,460 ± 95

*$R = (^{14}C/^{13}C)_{sample}/(^{14}C/^{13}C)_{standard}$ with 5050 B.C. wood used as the standard. †Measured $^{13}C/^{12}C$ ratio is −25.54 ± .02 per mil with reference to Pee Dee belemnite standard (*24*).

prepared from CO_2 from the three chemical fractions of the Sunnyvale bone sample are listed in Table 2. Preliminary values for ^{14}C determinations obtained by direct counting were previously reported (*22*) and were expressed with respect to 5050 B.C. wood. The values cited here represent a large number of subsequent measurements and have been expressed in ^{14}C years B.P.

The oldest radiocarbon value of approximately 5000 ^{14}C years B.P. is exhibited on the total NaOH-soluble organic fraction (UCR-1437B/AA-52). We would suggest that the most probable age of the Sunnyvale skeleton is between 3500 and 5000 ^{14}C years B.P. However, we recognize that the organic separation and purification techniques employed are not necessarily completely effective for all bone samples (*23*). Nevertheless, we are not aware of any instance where undetected contamination in carefully prepared, known-age bone samples has documented anomalies of the magnitude required to bring the indicated ^{14}C ages of the organic fractions of the Sunnyvale bone into agreement with its racemization-deduced age.

The ^{14}C values obtained on the Sunnyvale skeleton clearly assign it to the middle Holocene. This age assignment is fully consistent with the geologic, archeological, and anthropometric evidence and with associated ^{14}C determinations. The age of the Sunnyvale hominid deduced from its aspartic acid D/L ratio differs by more than an order of magnitude from that indicated by the ^{14}C values. The uranium series–derived age estimate also appears to be somewhat discordant when compared with the ^{14}C determinations, although there is certainly a possibility that modern carbon contamination in the bone was not totally excluded by the purification techniques employed in the ^{14}C analysis.

R. E. TAYLOR
LOUIS A. PAYEN
Radiocarbon Laboratory, Department of Anthropology, Institute of Geophysics and Planetary Physics, University of California, Riverside 92521
BERT GEROW
Department of Anthropology, Stanford University, Palo Alto, California 94305
D. J. DONAHUE
T. H. ZABEL
A. J. T. JULL
P. E. DAMON
NSF Regional Facility for Radioisotope Dating, University of Arizona, Tucson 85721

References and Notes

1. J. L. Bada and P. M. Helfman, *World Archaeol.* **7**, 160 (1975).
2. G. L. Isaac, in *Calibration of Hominoid Evolution*, W. W. Bishop and J. A. Miller, Eds. (Univ. of Toronto Press, Toronto, 1972), pp. 381–430.
3. F. C. Howell, in *Evolution of African Mammals*, V. J. Maglio and H. B. S. Cooke, Eds. (Harvard Univ. Press, Cambridge, Mass., 1978), pp. 154–248.
4. G. F. Carter, in *Early Man in America from a Circum-Pacific Perspective*, A. L. Bryan, Ed. (Occasional Paper 1, Department of Anthropology, University of Alberta, Edmonton, 1978), pp. 10–19.
5. E. L. Davis, G. Jefferson, C. McKinney, *Anthropol. J. Can.* **19**, 2 (1981).
6. One popular, pseudoscientific work has used the alleged 70,000-year age of the Sunnyvale skeleton to support an assertion that modern *Homo sapiens* evolved in North America [J. Goodman, *American Genesis* (Summit Books, New York, 1981)].
7. C. V. Haynes Jr., in *Pleistocene Extinctions: The Search for a Cause*, P. S. Martin and H. E. Wright, Jr., Eds. (Yale Univ. Press, New Haven, Conn., 1967), pp. 267–286.
8. R. E. Taylor and L. A. Payen, in *Advances in Archaeological Method and Theory*, M. Schiffer, Ed. (Academic Press, New York, 1979), pp. 239–283.
9. B. A. Gerow, *Soc. Calif. Archaeol. Occas. Pap.* *3* (1981), p. 1.
10. K. R. Lajoie, E. Peterson, B. Gerow, in *Biogeochemistry of Amino Acids*, P. E. Hare, T. C. Hoering, K. King Jr., Eds. (Wiley, New York, 1980), pp. 477–489.
11. B. A. Gerow with R. W. Force, *An Analysis of the University Village Complex With a Reappraisal of Central California Archaeology* (Stanford Univ. Press, Stanford, Calif., 1968), pp. 24–25 and 140 and map 2.
12. J. L. Bischoff and R. J. Rosenbauer, *Science* **213**, 1003 (1981).
13. J. L. Bada and R. Finkel, *ibid.* **217**, 755 (1982).
14. J. L. Bischoff and R. J. Rosenbauer, *ibid.*, p. 756.
15. R. E. Taylor, *Radiocarbon* **24**, 54 (1982).
16. ———, *ibid.* **22**, 969 (1980).
17. ———, in *Nuclear and Chemical Dating Techniques: Interpreting the Environmental Record*, L. A. Currie, Ed. (American Chemical Society, Washington, D.C., 1982), pp. 453–473.
18. ———, *Radiocarbon*, in press.
19. D. J. Donahue, T. H. Zabel, A. J. T. Jull, P. E. Damon, K. H. Purser, *ibid.*, in press. Measurements were made at the NSF Regional Accelerator Facility at the University of Arizona, Tucson.
20. C. W. Ferguson, personal communication.
21. J. Klein, J. C. Lerman, P. E. Damon, E. K. Ralph, *Radiocarbon* **24**, 103 (1982).
22. R. E. Taylor, paper presented at the 11th International Radiocarbon Conference, University of Washington, Seattle, 24 June 1982.
23. V. Haynes, *Science* **161**, 687 (1968).
24. Stable isotope value from A. Williams (personal communication).
25. We thank R. Berger, G. L. Isaac, and P. Wilke for their comments on the manuscript and C. Prior and P. J. Slota, Jr., for laboratory assistance. UCR Radiocarbon Laboratory research is supported by NSF grants BNS 7815069 and 8011764 (Anthropology Program). The Regional Accelerator Facility at the University of Arizona is supported by a National Science Foundation Regional Instrumentation Facilities grant. This is contribution 82/11 of the Institute of Geophysics and Planetary Physics, University of California, Riverside.

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Winteraceous Pollen in the Lower Cretaceous of Israel: Early Evidence of a Magnolialean Angiosperm Family

Abstract. *Pollen of the primitive angiosperm family Winteraceae has been discovered in the Aptian-Albian of Israel, extending the fossil record of this phylogenetically important family of flowering plants from the uppermost Upper Cretaceous back some 40 million years to the upper Lower Cretaceous. This appears to represent the earliest known record of a magnolialean angiosperm family and is convincing evidence for the existence in the Early Cretaceous of an extant family of angiosperms.*

The early fossil record of the angiosperms or flowering plants consists almost entirely of isolated parts of various organs that only rarely can be related to the same plant. The paleobotany of early angiosperms has therefore mostly been concerned with the separate study of diverse kinds of angiosperm megafossils (leaves, wood, flowers, fruits, and seeds) and microfossils (pollen grains, cuticle, and wood fragments). This fact, coupled with the strong bias of most early paleobotanical investigations toward the study of angiosperm leaves, helped contribute to a situation that puzzled botanists for many years—namely the apparent rapidity with which the angiosperms seemed to appear approximately 115 million years ago late in the Early Cretaceous. It has become clear that the seeming sudden appearance of angiosperms in the fossil record was an erroneous impression resulting from the misidentification of early fossil angiosperm leaves as the leaves of relatively advanced living angiosperms (*1*).

Although spectacular finds of early fossil angiosperm floral parts occasionally occur (*2*), most of the new insight into the early history of the flowering plants has been gained from study of early fossil angiosperm pollen grains along with the critical reexamination of early fossil angiosperm leaves (*1*). Although some Early Cretaceous leaves show systematic affinities with extant angiosperms, and in particular with the order Magnoliales, which is widely considered to be the most primitive group of living flowering plants (*3*), none apparently is referable to any extant angiosperm family (*4*). This is not the case with the fossil angiosperm pollen from the Early Cretaceous that we describe.

In his review of the fossil pollen records of extant angiosperms, Muller (*5*)