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ARIZONA RADIOCARBON DATES IV*

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INTRODUCTION

C^{14} measurements reported here were made in this laboratory between December 1, 1961 and October 1, 1962. Sample descriptions are classified as follows:

I. Tree-ring dated samples.
II. Modern shells from Santa Barbara County, California.
III. Archaeologic samples.
IV. Palynologic samples.
V. Geologic samples.
VI. C^{14} content of caliche.
VII. Water samples.
VIII. Modern organic sample.

Except for the caliche samples and samples A-209, A-210 and A-296, Part V, all samples have been reported in the usual manner either as ages in years or as Δ values (Lamont VIII). Because of the slow and variable rate of accumulation of caliche, the use of % modern activity, where modern activity is taken as 95% of standard oxalic acid, is less misleading. Standard deviations are computed from random counting errors only.

All organic samples were treated with 2% NaOH, when possible to do so without dissolving the sample itself, and with HCl to remove carbonate. The surfaces of carbonate samples were leached with HCl to remove a thin outer portion before collecting the CO_2 by hydrolysis with 50% H_3PO_4 or HNO_3.

In order to evaluate the veracity of wood and charcoal dates, we have determined the C^{14} content of a number of wood samples of known age. The University of Arizona Laboratory of Tree Ring Research supplied us with dendrochronologically dated *Pinus ponderosa* and *Sequoia gigantea* (sample description, Part I). W. Y. Adams supplied us with acacia samples from the 12th dynasty reign of Pharaoh Sesostris (= Senusret) III (sample description, Part III and Arizona III). The Δ values for these samples are shown in Figure 1. The value for an additional acacia sample from Zoser's tomb, Sakkara, Egypt (A-219, Arizona III) is also plotted. The Δ values are computed relative to 95% standard oxalic acid as modern activity and the year A.D. 1950 as zero time. Because the $\delta\ C^{14}$ figures from which Δ is computed are age-corrected (Lamont VI), the known age becomes zero time and Δ measures a C^{14} anomaly. The standard error of Δ and the age uncertainty are given as vertical and horizontal lines. The half life of C^{14} is taken as 5570 yr but a reference line for $T\frac{1}{2} = 5730$ is also given for comparison.

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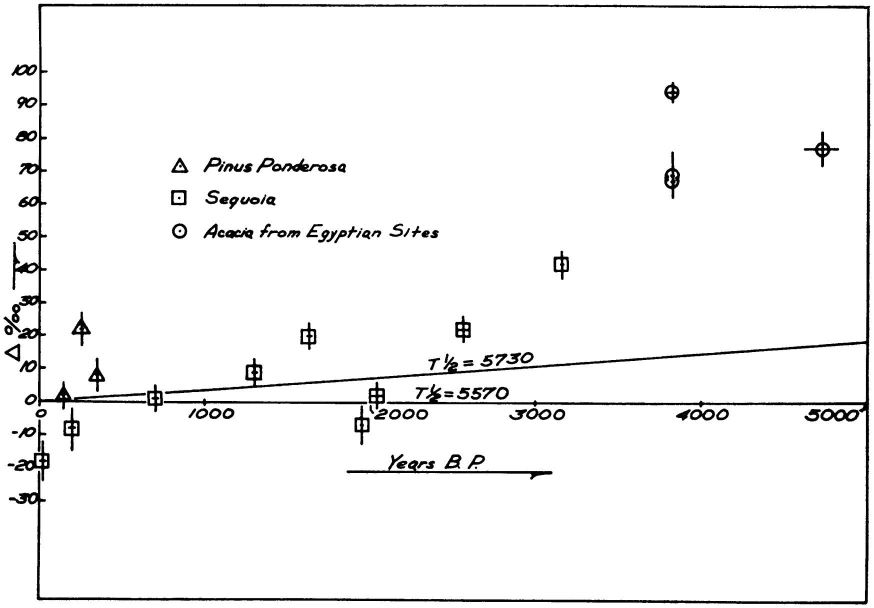

Fig. 1. C^{14} Excess or Deficiency vs. Time (corrected for fractionation).

The youngest Sequoia sample (A-255:6) definitely shows the Suess effect. The *Pinus ponderosa* samples were specifically selected to check the de Vries maximum at A.D. 1690 (de Vries, 1959, p. 81). Our results definitely confirm the large positive Δ C^{14} fluctuation at that time. With the exception of the A.D. 1690 maximum and the wood sample affected by industrial carbon, all samples fall within $\Delta = \pm 1.5\%$ of the T½ = 5730 reference line from the 1st century B.C. to the present time. Samples beyond 2500 B.P. have steadily increasing Δ values.

The 12th dynasty acacia samples are of particular importance because the key astronomical date for fixing in time of the Egyptian Middle Kingdom occurs in the 7th year of the reign of Pharaoh Sesostris III (Hayes, *et al.*, 1962, p. 1-2). These samples are also valuable because the acacia wood is probably not much older than the structure in which it was found. Many wood samples, e.g., large planks of cedar, are undoubtedly much older than the structure in which they are found and therefore must be rejected where precise dating is necessary. The dates for the reign of Pharaoh Zoser are much less certain, as indicated in the diagram by the horizontal uncertainty line.

The cause of the large apparent excess of C^{14} beyond 2500 B.P. does not appear to be the result of an underestimation of the half life of C^{14} as indicated by the fairly close agreement for younger samples. Two remaining possible causes are (1) variation in the C^{14} production rate and (2) fluctuation of the total CO_2 content of the atmospheric reservoir. Although the first possibility cannot be eliminated at this time, it would seem to the authors that fluctuation of the total content of the atmospheric reservoir is not only possible but quite probable. Much more work is necessary before this phenomenon can be properly evaluated. However, such large fluctuations of the initial C^{14} content of wood call for caution in the evaluation of C^{14} dates as absolute sidereal years. In particular, the fixing by C^{14} dating, of floating archaeologic chronologies such as the Babylonian chronology (Libby, 1955, p. 81-82), cannot be successfully accomplished without reference to the C^{14} content of samples of known age. Knowledge of the C^{14} content of contemporaneous samples of known age has been used by Satterthwaite and Ralph (1960) to correlate the Mayan calendar with the Christian. Their work illustrates the correct approach to the solution of such correlation problems. As more data on the C^{14} content of samples of known age become available, determination of absolute C^{14} ages will become increasingly accurate.

ACKNOWLEDGMENTS

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The C^{13} data reported in this date list were all provided through the kind cooperation of W. R. Eckelmann of Jersey Production Research Corporation.

We are particularly appreciative of the cooperation provided by J. C. Vogel of the Physikalisches Institut, University of Heidelberg, in the setting up of equipment for the dating of water samples and to J. G. Ferris of the U. S. Geological Survey for advice and guidance in the selection of samples.

W. M. Harrison provided the modern shells used as controls on C^{14} shell dates. Catheryn MacDonald assisted in laboratory analyses.

SAMPLE DESCRIPTIONS

I. TREE-RING DATED SAMPLES

Ponderosa pine FL-9 series, Arizona

Wood, *Pinus ponderosa,* from Flagstaff area, Coconino Co. (35° 08′ N Lat, 114° 40′ W Long). Coll. 1906 by A. E. Douglass; subm. 1962 by M. A. Stokes, Lab. of Tree Ring Research, Univ. of Arizona, Tucson. *Comment*: tree began growth in A.D. 1526 and was cut in A.D. 1906.

	δC^{14},‰	δC^{13},‰	Δ,‰
A-354:1. Tree rings A.D. 1596 to A.D. 1609 age span.	**13 ± 5**	**−22.4**	**8 ± 5**
A-354:2. Tree rings A.D. 1688 to A.D. 1692 age span.	**27 ± 5**	**−22.4**	**22 ± 5**
A-354:3. Tree rings A.D. 1795 to A.D. 1804 age span.	**8 ± 4**	**−21.7**	**2 ± 4**

Sequoia No. 3 series, California

Wood, *Sequoia gigantea,* from Giant Forest, Sequoia Natl. Park (36° 35′ N Lat, 118° 48′ W Long). Coll. 1959 by H. N. Michael, Univ. of Pennsylvania;

subm. by M. A. Stokes. *Comment*: tree began growth ca. 215 B.C. and was cut in A.D. 1950.

	δC^{14},‰	δC^{13},‰	Δ,‰
A-255:1. Tree rings	**12 ± 4**	**(−20.2)**	**2 ± 4**
124 B.C. to 60 B.C. age span. C^{13} value is average of four analyses for Sequoia No. 3 wood.			
A-255:7. Tree rings	**3 ± 6**	**(−20.2)**	**−7 ± 6**
6 B.C. to A.D. 4 age span.			
A-255:2. Tree rings	**30 ± 4**	**−20.2**	**20 ± 4**
A.D. 310 to A.D. 330 age span.			
A-255:3. Tree rings	**20 ± 4**	**−19.5**	**9 ± 4**
A.D. 643 to A.D. 660 age span.			
A-255:4. Tree rings	**10 ± 7**	**−20.8**	**1 ± 4**
A.D. 1235 to A.D. 1270 age span.			
A-255:5. Tree rings	**2 ± 6**	**−20.3**	**−8 ± 6**
A.D. 1725 to A.D. 1770 age span.			
A-255:6. Tree rings	**−9 ± 4**	**(−20.2)**	**−18 ± 4**
A.D. 1910 to A.D. 1949 age span.			

Sequoia D-21 series, California

Wood, *Sequoia gigantea*, from Converse Height mill site, Sequoia Natl. Forest (36° 48′ N Lat, 118° 58′ W Long). Coll. 1918 by A. E. Douglass; subm. 1962 by M. A. Stokes. *Comment*: tree began growth in 1305 B.C. and was cut in logging operations ca. A.D. 1890 to A.D. 1910.

	δC^{14},‰	δC^{13},‰	Δ,‰
A-326. Tree rings	**33 ± 4**	**−19.9**	**22 ± 4**
641 B.C. to 566 B.C. age span.			
A-327. Tree rings	**51 ± 4**	**−20.6**	**42 ± 4**
1211 B.C. to 1195 B.C. age span.			

II. MODERN SHELLS FROM SANTA BARBARA COUNTY, CALIFORNIA

These samples were run as controls for similar shells from four distinct sites in Santa Barbara Co. (sample descriptions, Part III) ranging in age from over 6000 yr to the Colonial period. All dates are reported as usual relative to 95% oxalic acid taken as modern activity and without C^{13} correction; only the standard deviation due to counting statistics has been used. *Comment*: shells appear to be 150 ± 50 yr older than modern charcoal corrected for the Suess effect and bomb effect. As ages of carbonates, so computed, should be zero or negative, the apparent age may be due to upwelling of "old" water off the

Santa Barbara coast or it may be a pre-bomb Suess effect. The different ages may be due entirely to statistical error and different amounts of C^{13}/C^{12} fractionation. However, a variable contribution of bomb C^{14} is also possible.

A-322. Red Abalone, RC-2 **210 ± 50**
A.D. 1740

Haliotis rufescens collected off Santa Rosa Island (33° 55′ N Lat, 120° 5′ W Long), near Santa Barbara, water depth ca. 20 ft. Coll. 1961 by D. Wilson, Santa Barbara, Calif.; subm. by W. M. Harrison, Univ. of Arizona.

A-357. Pink Abalone, RC-1 **170 ± 50**
A.D. 1780

Haliotis corrugata collected off San Miguel Island (34° 5′ N Lat, 120° 20′ W Long), near Santa Barbara, water depth ca. 20 ft. Coll. 1961 by D. Wilson; subm. by W. M. Harrison.

A-358. Mussel shell, RC-3 **80 ± 50**
A.D. 1870

Mytilus californianus collected at Dos Pueblos Ranch near Santa Barbara (34° 30′ N Lat, 120° 0′ W Long). Coll. 1961 by W. M. and E. S. Harrison; subm. by W. M. Harrison.

III. ARCHAEOLOGIC SAMPLES

A-204. Tucson, Arizona **850 ± 180**
A.D. 1100

Organic material mixed with ash from isolated hearth, SE ¼ of residential lot, 6730 N Casas Adobes Drive (32° 14′ N Lat, 110° 53′ W Long). Coll. 1959 and subm. 1960 by J. D. Hayden, Dept. of Anthropol., Univ. of Arizona. No artifacts were associated with hearth but both oxidized and unoxidized artifacts and cairns containing basal stones with heavy ground patina are found along trails in this area. *Comment*: although the oxidized artifacts in the area are of San Dieguito I pattern, the hearth is evidently much younger, i.e. of ceramic age. Carbonates were removed by leaching in dilute HCl. Sample was free of rootlets.

Semna series, Sudan

Wood from mud brick fortress of Semna on bank of the Nile, ca. 60 mi S of the Egyptian frontier (21° 30′ N Lat, 30° 58′ E Long). Coll. 1960 and subm. by W. Y. Adams, UNESCO Programme Specialist, P. O. Box 178, Khartoum, Sudan.

A-205. Semna I **3290 ± 120**
1340 B.C.

From timber near base of S wall.

A-206. Semna II **3300 ± 120**
1350 B.C.

From timber 10 yd from Semna I timber.
Comment: hieroglyphic texts associate the building of the fortress with the Pharaoh Sesostris (= Senusret) III. His reign has been determined by the astronomical chronology as beginning at 1887 B.C. and ending 1849 B.C.

(3799-3837 B.P.). Although additions were made as late as 1500 B.C., Adams believes it certain that the girdle walls are among the original features of the site. This discrepancy is of the same magnitude and direction as observed for other Egyptian sites (e.g., see A-207 and A-219, Arizona III). Because of their importance, we made three separate burnings of A-205 and two separate burnings of A-206, and the results are averaged.

Gua Sirih Cave series, Borneo

Charcoal samples from a dwelling cave in S Sarawak (1° 15′ N Lat, 110° 25′ E Long). Coll. 1959-1960 and subm. by W. G. Solheim, Dept. of Anthropol., Univ. of Hawaii. Excavation of this cave is sponsored by the Sarawak Mus.

A-280. Charcoal, 30 to 36 cm depth **<1600**

Excavation coordinates (5 ft grid) S half M10. *Comment*: only 0.1 L of CO_2 was obtained from this minute charcoal sample. According to Solheim, stone tools from approximately this level are typologically Mesolithic and similar to Mesolithic tools from Niah Cave. It appears charcoal was not related to the tools.

A-281. Charcoal, 5 to 10 cm depth **620 ± 260**
A.D. 1330

Excavation coordinates, M10.

A-282. Hearth sample **714 ± 330**
A.D. 1236

Excavation coordinates, D8, from small hearth directly on "sterile" soil at base of deposit. *Comment*: expected age, according to Solheim, is close to 2000 B.P. dating the earliest occupation of the cave by pottery-making people related to the pottery makers from Niah Cave (Solheim, 1961).

A-283. Hearth sample, 30 to 36 cm depth **4480 ± 100**
2530 B.C.

Excavation coordinates, C9, from hearth in S wall of trench. *Comment*: expected age, according to Solheim, is between 500 and 2000 B.P. Artifacts indicate relation with Late Neolithic-Early Iron Age level in Niah Cave.

A-284. Natural Cave, Arizona **603 ± 60**
A.D.1347

Panic grass seeds found with squash seeds and red and white tepary beans contained in a twined-woven bag, under 5 ft of bat guano on floor of Natural Cave in Trigo Mtns. of W Yuma Co. (33° 15′ N Lat, 114° 35′ W Long), 8 mi E of Colorado River. Coll. 1961 by H. and D. Yowell; subm. by E. W. Haury, Arizona State Mus., Univ. of Arizona. *Comment*: only panic grass seed used for assay.

Buhen Old Kingdom series, Sudan

Charcoal from copper smelting site at Buhen in Nubia near Wadi Halfa, Sudan (21° 51′ N Lat, 31° 17′ E Long). Coll. 1962 by W. B. Emery; subm. by W. Y. Adams. Site was discovered December 1961 and is currently under excavation by the Egypt Exploration Soc. under direction of Prof. W. B. Emery of London Univ. College. According to Adams, it represents the first substantial evidence of Egyptian Old Kingdom occupation in Nubia. It is dated both by an abundance of Old Kingdom pottery and by inscribed jar seals and ostraka. The names of King Khafre and Menkaure of the 4th dynasty and Userkaf, Sahure and Nuserre of the 5th dynasty have been recognized. The site comprises a complex of domestic and workshop buildings extending along the bank of the Nile for at least 0.25 mi and enclosed by a crude stone fortification wall. The site has been repeatedly inundated by the Nile. Evidence for copper smelting consists of cylindrical furnaces, copper ore and slag, and pottery moulds and crucibles scattered throughout the site.

A-330. Charcoal **3960 ± 60**
2010 B.C.

A-331. Charcoal **3960 ± 60**
2010 B.C.

A-332. Charcoal **3820 ± 50**
1870 B.C.

These three samples are from loose sand within 20 cm of surface and above habitation floors which can definitely be ascribed to 4th or 5th dynasties. *Comment*: according to Hayes, *et al.* (1962), the 4th and 5th dynasties extend from ca. 2610 B.C. to 2340 B.C. (4560 B.P. to 4290 B.P.)

A-333. Charcoal **4190 ± 60**
2240 B.C.

A-334. Charcoal **4090 ± 50**
2140 B.C.

Both samples are from 1.5 m below the intact habitation floors of the 4th or 5th dynasties above and in a deposit of sand and refuse which may date from the 2nd dynasty (based on the size of broken bricks found in the same deposit). *Comment*: according to Hayes, the 2nd dynasty terminates ca. 2690 B.C. (4640 B.P.). Thus the C^{14} date is definitely younger than expectation, based upon the archaeologic provenience (see comment, Semna series).

Dos Pueblos Ranch Colonial series, California

Charcoal and shells from the Dos Pueblo Ranch site, 4SBa78 Area 1 Section A, occupied during Colonial time, ca. A.D. 1542 to A.D. 1800, Santa Barbara Co. (34° 30′ N Lat, 120° 0′ W Long). Five-foot grid pattern used throughout. Coll. 1958 and subm. by W. M. Harrison. Samples were run as a control for C^{14} age determination on neighboring sites. See Part II (sample descriptions) for modern shells from off Santa Barbara coast. Note that charcoal sample (A-298) and the two abalone shells (A-300, A-301) do not show the 150-yr difference which would be expected from the activity of modern shells.

A-297. Charcoal, RC-4 **0 ± 55**
A.D. 1950

Burnt log resting on floor of structure (N14 W16). *Comment*: modern "date" of this sample is not irreconcilable with known age of the site in light of work done by de Vries (1959, p. 81) and this laboratory. De Vries has demonstrated, from measurements of charred wheat and trees from the Bavarian and Spesart forests, the existence of an atmospheric C^{14} maximum of ca. 4% to 5% above modern at A.D. 1690. To check this, we measured A.D. 1690 pine tree rings (A-354:2, Part I) from Flagstaff and got 60 ± 50 B.P.

A-298. Charcoal, RC-5 **250 ± 55**
A.D. 1700

Burnt log with one end lying on floor of feature and other end projecting a few inches above floor (N14 W17). *Comment*: this specimen, not showing the anomalously young age of A-297, probably more closely represents the true age of the feature. The portion analyzed, however, may have come from the center of a log while A-297 may have come from the younger, outer circumference or from a smaller log. There is no way to determine for sure whether the differences measured in these samples are initial atmospheric, tree ring, or real age differences.

A-300. Abalone shell, RC-7 **180 ± 55**
A.D. 1770

Haliotis (?) from within 2 in. above floor of Feature 1 (N12 W15).

A-301. Abalone shell, RC-8 **250 ± 50**
A.D. 1700

Haliotis cracherodi from ca. 1 in. above floor of Feature 1 (N15 W18).

Rincon Point series, California

Shells and charcoal from Rincon Point, 4 SBa 119, Santa Barbara Co. (34° 25′ N Lat, 119° 30′ W Long). Quadrant system used in 9′ x 10′ pit. Subm. by W. M. Harrison.

A-323. Red Abalone, RC-13 **3270 ± 250**
1320 B.C.

Haliotis rufescens from 38 in. below surface, associated at pelvis of skeleton and within rock cairn outlining grave at Burial 4, SW quadrant. Coll. 1959 by Patricia Lyon.

A-324. Black Abalone, RC-14 **3420 ± 130**
1470 B.C.

Haliotis cracherodi from Association No. 2 of Burial 8 occurring under the fragmented end of the right ulna, NE quadrant. Coll. 1960 by Patricia Lyon.

A-325. Charcoal, RC-15 **29,000 ± 1000**
27,050 B.C.

From 36 to 42 in. level, in soil from the grave matrix of Burial 2, i.e., entirely outside of the disturbed grave soil, NE quadrant. Coll. 1959 by W. M. Harrison. *Comment*: in light of the other dates of this site (especially A-340) and the archaeological context, this charcoal must have been redeposited from an old burned forest.

A-340. Clam Shell, RC-16 **3530 ± 60**
1580 B.C.

Tivela stultorum from 42 to 48 in. level, below and outside of the grave of Burial 2, NE quadrant. Coll. 1959 by W. M. Harrison.

Aerophysics series, California

Shells from 4 SBa 53, Santa Barbara Co. (34° 30′ N Lat, 119° 50′ W Long). Five-foot grid pattern employed. Coll. 1956-57 and subm. by W. M. Harrison. *Comment*: contrary to tentative archaeologic sequence as derived by Harrison based on burial position of human skeleton, the Aerophysics cemetery appears to be older than Rincon Point cemetery. These sites are midden matrix and cultural material is not abundant in them.

A-302. Clam, RC-11 **4890 ± 80**
2940 B.C.

Tivela stultorum from an extensive layer of this species between 15 and 18 in. level below the modern surface (N1 E8, Area B).

A-303. Abalone, RC-12 **4620 ± 80**
2670 B.C.

Haliotis rufescens from 12 to 18 in. below the modern surface (N1 W18, Area A).

A-363. Abalone, RC-26 **4980 ± 60**
3030 B.C.

Haliotis rufescens from 24 to 30 in. below present surface (N13 E26, Area A).

Dos Pueblos Ranch, older series, California

Shells from 4SBa 78, Santa Barbara Co. (34° 30′ N Lat, 120° 0′ W Long). Coll. 1959 and subm. by W. M. Harrison. *Comment*: based largely on burial positions and very sparse or lack of cultural associations, the expected time range was 7000 B.C. (Stratum C) to A.D. 1800 (Stratum A). Estimates were tentative, as ultimate chronology is to rest on C^{14} results. From the above dates, Stratum A is not contemporary to the Colonial site at Dos Pueblos, and the oldest date thus far is less than 5000 B.C.

A-349. Abalone, RC-10 **4110 ± 80**
2160 B.C.

Haliotis rufescens from Stratum A of the cemetery, resting against skull of Burial 9 (N144 E60, Area 3). *Comment*: considering the dates listed below from Stratum B beneath this specimen, this shell probably was a relic or souvenir buried with the body rather than remains of a meal. Bones from Burial 9 will be dated when available.

A-377. Clam, RC-27 **3700 ± 80**
1750 B.C.

Tivela stultorum from 18 to 24 in., lowest level in Stratum A (N145 E60, Area 3).

A-345. Clam, RC-19 **3860 ± 80**
1910 B.C.

Tivela stultorum from 18 to 24 in. below present surface (top 6 in. of Stratum B), (N145 E59 and N146 E59, Area 3, Section A).

A-346. Clam, RC-20 **4530 ± 180**
2580 B.C.

Tivela stultorum from 24 to 30 in. below present surface, 6 to 12 in. below top of Stratum B (N145 E59 and N145 E60, Area 3, Section A).

A-376. Clam, RC-28 **6830 ± 90**
4880 B.C.

Tivela stultorum from 24 to 30 in. below present surface, 6 to 12 in. below top of Stratum B, burial matrix of Burial 19 (N146 E60 and N146 E59, Area 3, Section A). *Comment*: this shell may have been redeposited by grave diggers from deeper in this nearly homogeneous midden.

A-347. Clam, RC-22 **4430 ± 70**
2480 B.C.

Tivela stultorum from 30 to 36 in. below modern surface in Stratum C (N146 E59 and N146 E60, Area 3, Section A).

A-348. Clam, RC-23 **5320 ± 70**
3370 B.C.

Tivela stultorum from 30 to 36 in. below modern surface in Stratum C (N146 E59 and N146 E60, Area 3, Section A).

A-362. Mussel, RC-25 **6520 ± 80**
4570 B.C.

Mytilus californianus from 30 to 36 in. below present surface in Stratum C (N145 E59 and N145 E60, Area 3, Section A).

A-356. Clam, RC-18 **5330 ± 80**
3380 B.C.

Tivela stultorum from 22 in. below present surface near pelvis of Burial 2 (W edge of Pit N2 W25, Area 1, Test Pit 3) tentatively correlated as 6 in. below top of Stratum B.

IV. PALYNOLOGIC SAMPLES

Murray Springs series, Arizona

Organic material in earth from ARIZ:EE:8:13, Cochise Co. (31° 35′ N Lat, 109° 10′ W Long), 2.7 km W of Lewis Spring on an arroyo tributary to the San Pedro River. Coll. 1959 by P. S. Martin and J. Schoenwetter; subm. by P. S. Martin, Geochronology Labs., Univ. of Arizona, Tucson.

A-186. Earth **4120 ± 490**
2170 B.C.

Sample from 210 cm below surface containing some disseminated charcoal. Dominant pollen type: Cheno ams (Martin, *et al.*, 1961). *Comment*: date must be considered minimal because of possible post-depositional contamination.

A-187. **5280 ± 330**
3330 B.C.

Earth sample from 270 cm below surface with low organic content. *Comment*: sample was leached with HCl to remove high carbonate content and many rootlets were removed. Dominant pollen type: Compositae (Martin, idem). Martin, *et al.*, correlated this sample with their Pollen Zone V (see Double Adobe series below). The date does not confirm this interpretation. If samples A-186 and A-187 were not affected by post-depositional contamination, they represent Altithermal deposition. Sedge, cattail, and tree pollen are slightly more abundant between 200 and 300 cm than higher in the section.

Double Adobe series, Arizona

ARIZ:FF:10:1, 2.1 km N of Double Adobe, Cochise Co. (31° 29′ N Lat, 109° 43′ W Long). A Cochise culture site. For pollen analysis see Martin, *et al.* (1961).

A-190. Carbonaceous earth **7910 ± 200**
5960 B.C.

Sample from Martin's Pollen Zone V, dominated by Compositae, (Martin, idem). Coll. 1959 and subm. by P. S. Martin.

A-191. Carbonaceous earth **8000 ± 60**
6050 B.C.

Sample from 100 cm below bench surface in sediment of Sulphur Spring age, representing the base of Martin's Pollen Zone VI, dominated by Compositae. Coll. 1959 and subm. by P. S. Martin.

A-189. Charcoal **8960 ± 100**
7010 B.C.

Soil with disseminated charcoal **8680 ± 100**
6730 B.C.

Sample from 25 to 50 cm below bench surface in sediment of Sulphur Spring age in Martin's Pollen Zone VI, dominated by Compositae, (Martin, idem). Coll. 1959 by D. Shutler; subm. by P. S. Martin. *Comment*: the younger ages on total soil in this case and for A-191 are most probably the result of contamination with younger organic matter. Other Arizona dates for Martin's Pollen Zone VI at the Double Adobe site are: A-184C, 8240 ± 960; A-184E, 7030 ± 260; A-188C, 8270 ± 250; A-188E, 8260 ± 160 (Arizona III). All C^{14} dates by Martin, *et al.*, for Pollen Zones V and VI within the immediate vicinity of the Sulphur Spring type site, fall within the postglacial 7000 to 9000 B.P. age range.

A-194. Whitewater Draw, Arizona **2860 ± 440**
910 B.C.

Organic material in earth from pithouse of San Pedro stage on E bank of Whitewater Draw, 2.8 mi NW of McNeal generating plant, T22S R26E Sec. 8, (31° 32′ N Lat, 109° 43′ W Long), Cochise Co. Sample taken 135 to 145 cm below bottom of pithouse. Dominant pollen type: Cheno-ams. Coll. 1959 by P. S. Martin. *Comment*: the probability of post-depositional contamination of this type of sample is greater than for a date on charcoal. A charcoal sample from floor of the pithouse, A-193, was dated at 3860 ± 200 (Arizona III).

Matty Canyon series, Arizona

Matty Canyon-Cienega Creek area, T19S R17E Sec. 17, Pima Co. (31° 51′ N Lat, 110° 35′ W Long). Other dates from the Matty Canyon are: for upper stratum, A-88 bis, 2010 ± 150; Sh-5664-7, 1850 ± 70; and for lower stratum, A-92, 2220 ± 150; Sh-5665-10, 2470 ± 100 (Arizona III).

A-196. Cienega material **2190 ± 100**
240 B.C.

Decayed plant material taken from 3E-3F boundary (see Eddy and Cooley, Anthropol. Papers, Univ. of Arizona Press, in preparation). Coll. 1957 by F. W. Eddy and D. Shutler, Jr.; subm. by Shutler.

A-227A. Carbonaceous earth **2140 ± 60**
190 B.C.

A-227B. NaOH-soluble fraction **1790 ± 400**
A.D. 160

Sample taken 375 ft upstream from Section MC6 (Eddy and Cooley, idem), E bank, 630-650 cm below surface. Dominant pollen type: Compositae. Coll. 1958 and subm. by P. S. Martin. *Comment*: A-227A was treated in the usual manner. A-227B is the NaOH soluble fraction leached from A-227A. The soluble fraction appears to be younger but the two numbers are within standard deviation.

A-256. Laguna Salada **7300 ± 110**
5350 B.C.

Dark colored, clay-silt sample from alluvial fill exposed near Floy in a large arroyo leading into the NW end of Laguna Salada near Rte. 665 between Show Low and Concho, Apache Co. (34° 21′ N Lat, 110° 17′ W Long). Sample collected ca. 1 m below soil surface and ca. 15 cm above a distinct gray sand and gravel lens, ca. 15 m upstream from the old bridge abutments. Coll. 1961 by R. H. Hevly and M. E. Cooley; subm. by P. S. Martin, Chicago Nat. History Mus., Chicago, and R. H. Hevly, Geochronology Labs., Univ. of Arizona. *Comment*: this sample contained many fine fibrous rootlets which were meticulously removed by hand picking. The sample was leached in HCl to remove carbonate but was not leached with NaOH. Contribution of younger carbon is probably quite low but some contamination may be present. It postdates a maximum in pine-spruce pollen and coincides with a maximum in Compositae pollen.

A-268. Chuska Mountains, New Mexico **24,700 ± 3900**
22,750 B.C.

Core segment from Deadman Lake (36° 15′ N Lat, 108° 55′ W Long), Chuska Mtns. San Juan Co., N. Mex., 312-318 cm depth, in core No. 5826, just above sharp peak in the pine-pollen curve and a corresponding depression in the curve for *Artemisia* pollen (Bent, 1960). Coll. 1958 and subm. by H. E. Wright, Dept. of Geol., Univ. of Minn., Minneapolis 14, Minn. *Comment*: another date from same core: 7.25-735 m level, >28,000 (A-213, Arizona III); nearby core: 9 to 12 cm level, 3900 ± 300 (L-515A, Lamont VII).

A-306. Chuska Mountains, New Mexico **1270 ± 610**
A.D. 680

Organic material from core taken 17 to 19 cm below surface at Whisky Lake (35° 59′ N Lat, 108° 48′ W Long), San Juan Co., N. Mex. Sample dates the end of the alpine or subalpine vegetation phase (*Artemisia*-spruce zone) and beginning of the pine-pollen zone in the core. Coll. 1958 and subm. by

H. E. Wright. *Comment*: sample from pine zone, 25 cm above *Artemisia*-spruce zone at Deadman Lake was dated at 3900 ± 300 (L-515A, Lamont VII). Contamination in A-306 is quite possible considering that it is from near the top of the pond sediments. Large error is the result of a low CO_2 yield from the core.

V. GEOLOGIC SAMPLES

Elegante Crater series, Sonora, Mexico

Travertine samples from delta deposits in Elegante Crater, Pinacate Mountains, Sonora, Mexico (31° 48′ N Lat, 113° 31′ W Long). Coll. 1958 and subm. by P. E. Damon. *Comment*: according to Jahns (1959), the delta was built along the margin of a lake that occupied the crater soon after its collapse. Lake appears to have been at least 200 ft deep during most of its history followed by episodic recession, as suggested by remnants of well-defined topset benches at lower levels. Jahns believes the presence of this lake indicates the existence of the crater during the last pluvial period. Data bear out this expectation.

A-208. Delta on W side of crater **12,970 ± 560**
11,020 B.C.

A-261. Delta on E side of crater **17,200 ± 220**
15,250 B.C.

San Augustin Plains series, New Mexico

Organic-rich clay from San Augustin Plains, N. Mex. (33° 45′ N Lat, 107° 30′ W Long). Samples were collected 0.5 mi apart, each from 4 in. below surface near center of dry lake. Coll. 1960 by A. Long and C. Halva; subm. by Long.

A-209. San Augustin, modern **107.8 ± 3.0% modern**

A-210. San Augustin, modern **109.5 ± 3.8% modern**

Comment: post-modern count indicates sedimentation in the dry lake area has occurred since the atomic bomb tests.

A-296. San Jon, New Mexico **1.4 ± 0.6% modern**

Carbonate nodules in laminated red clay from San Jon "formation," San Jon site (35° 01′ N Lat, 103° 22′ W Long), Quay Co., New Mexico. Sample is believed to be precipitated from a pond and thus to be contemporaneous with laminated red clay zone. Coll. 1961 and subm. by J. Harbour, Mus. of New Mexico. *Comment*: the activity of modern carbonate can be considered the same (within 5%) as contemporary wood, but limestone, which may contribute half the carbon atoms in a bicarbonate solution, has zero activity. If one assumes the initial activity of the carbonate was 50% that of contemporary wood, the date would be 28,700 ± 1900. The initial value for carbonate precipitated from ground water solution should lie between 50% and 100%, so the true date may be even older. Evidently the laminated red clay of Zone 3 of the San Jon "formation" is older than the blue-gray pond clay which contains human artifacts (Judson, 1953).

A-221. Willcox Playa, Arizona **>20,000**

Organic material from core in center of Willcox Playa (32° 9′ N Lat, 109° 51′ W Long), Cochise Co. Sample from 140-ft core drilled for Geochronology Labs. Pleistocene pollen study, at depth of 5 ft below surface in green clays just below the oxidized zone. Coll. 1960 by B. C. Arms, Geochronology Labs., Univ. of Arizona; subm. by A. Long. *Comment*: the very low organic content of the sample necessitated dilution even for the 0.5 L counter; the age, a minimum, is at least not out of line with A-352 (this date list).

Willcox Playa carbonate series, Arizona

Carbonate fractions from core in Willcox Playa (32° 9′ N Lat, 109° 51″ W Long), Cochise Co. Levels are depths from top of 140-ft core drilled for Pleistocene pollen study. A-351 contained no pollen; A-352 and A-353 contained over 95% pine pollen. Coll. 1960 by B. C. Arms; subm. by P. S. Martin.

A-351. Willcox Playa, 19-27 in. **8615 ± 110**
6665 B.C.

A-352. Willcox Playa, 6 ft 3 in. to 7 ft **23,000 ± 500**
21,050 B.C.

A-353. Willcox Playa, 7 ft 8 in. to 8 ft 5 in. **22,000 ± 500**
20,050 B.C.

Comment: there was no discrete carbonate layer or even visible crystals, but the X-ray diffraction pattern of the clay showed calcite lines. Since sample A-351 is above the water table, this date must include modern contamination and should be considered minimal. A-352 and A-353 may represent the age of the sediments, but because of ground water movement in the area and the extremely small size of the carbonate crystals, mixing is possible. Interpretation of these numbers awaits assay of carbonate from ground water in this basin.

A-359. Dahlac Archipelago **17,200 ± 330**
15,250 B.C.

Carbonate sample from fossil reef ca. 6 m above sealevel, Dahlac Archipelago, E of Massaua, Ethiopia in S Red Sea (15° 53′ N Lat, 39° 55′ E Long). Coll. 1962 and subm. by Yaacov Nir, State of Israel Geol. Survey, Jerusalem. *Comment*: Dahlac Archipelago is situated at the western border of the Syrian-African rift system and at the northern edge of the Dankaiian Horst. According to Nir, this sample dates the time of the last uplift of the Archipelago and confirms the very recent age of the Dahlac. Sample was washed in dilute HCl before hydrolysis to remove possible recent contamination.

VI. C^{14} CONTENT OF CALICHE

Several samples of caliche were collected, mostly from Arizona, in order to compare C^{14} contents of caliche of different types and depths, and from different climatic environments. This was in connection with a study of the origin of caliche. Generally, they were found to be more radioactive nearer the surface of the ground, indicating formation by means of evaporation of meteoric water infiltrating through the unsaturated zone rather than evaporation of vadose water from the ground-water table. Also, the caliche found in presently more humid climates tended to contain more C^{14}, indicating a more rapid rate of formation in the grasslands than in the deserts. The results are reported as percent modern, i.e., 95% NBS oxalic acid. Standard deviation includes counting statistics only.

A. Caliche from Santa Cruz Valley, Arizona

Oracle Junction series

Caliche layer below soil zone, 1.5 ft thick, from recently excavated pit ca. 5 mi E of Oracle Junction (32° 35′ N Lat, 110° 55′ W Long), Pima Co., Arizona. Coll. 1961 and subm. by J. J. Sigalove.

A-224. Top of caliche zone **31.4 ± .8% modern**

A-222. 9 in. below top **10.4 ± .6% modern**

A-223. 19.5 ft below top **<3.1% (2 σ criterion)**

Arivaca Junction series

Caliche, beginning 4 ft below surface, from recently excavated pit 40 mi S of Tucson near Arivaca Junction (31° 45′ N Lat, 111° 5′ W Long), Santa Cruz Co., Arizona. Coll. 1961 and subm. by J. J. Sigalove.

A-240. Top, 4 ft below surface **4.0 ± 1.4% modern**

A-239. 10 ft below surface **3.0 ± 0.5% modern**

A-251. Sahuarita, Arizona **3.1 ± 0.6% modern**

"Brick-yard" locality (31° 55′ N Lat, 110° 58′ W Long), Pima Co., Arizona. Sample from calichified layer in which remains of *Equus*, *Mammuthus* and *Bison* were found ca. 10 ft below ground surface. Caliche was encrusting bones which are of Late Pleistocene age (J. F. Lance, oral communication). Coll. 1957 by J. F. Lance, Univ. of Arizona; subm. by J. J. Sigalove.

A-212. Tucson, Arizona **19.4 ± 1.3% modern**

Surface of wash bank, 50 yd E of First Ave. and ca. 1.5 mi N of River Road (32° 15′ N Lat, 110° 50′ W Long). Caliche covering cobbles and boulders of Catalina gneiss as well as making up part of the unconsolidated sediment in which cobbles and boulders were found. Coll. 1960 and subm. by J. J. Sigalove.

B. Caliche from Tucson Mountains, Arizona

These rocks are basic volcanics for the most part. The caliche, instead of forming in soil zones, forms in crevices and bottoms of drainage ditches. Locality is in Pima Co., Arizona (32° 15′ N Lat, 111° 10′ W Long).

A-218. Little "A" Mountain **47.9 ± 0.6% modern**

Hard, white deposit in crevice of light gray tuff. Coll. 1960 and subm. by J. J. Sigalove and P. E. Damon.

A-321. Tumamoc Hill **20.0 ± 0.4% modern**

Caliche 6 in. deep, from shallow drainage ditch along road to radio tower. Coll. 1962 and subm. by P. E. Damon.

A-308. Brown Mountain **2.8 ± 0.5% modern**

Caliche from arroyo at southern base of mountain. Coll. 1962 and subm. by P. E. Damon. *Comment*: sample from outer surface of thick caliche veneer observed on banks and extending into bottom of arroyo. The C^{14} content is consistent with formation during last pluvial episode.

C. Caliche from Other Parts of Southern Arizona and New Mexico

Vaughn series, New Mexico

Caliche samples from road cut in Rte. 54, near Vaughn (34° 26′ N Lat, 105° 27′ W Long). Caliche formed in limestone. Coll. 1961 and subm. by J. J. Sigalove.

A-249. Land surface **20.9 ± 1.2% modern**

A-248. Base of cut, 11 ft depth **<3.2% (2 σ criterion)**

Oracle series, Arizona

Samples from surface of ground in drainage gully N of Oracle (32° 44′ N Lat, 110° 43′ W Long), Pima Co. Coll. 1961 and subm. by J. J. Sigalove.

A-265. Oracle, surface **19.4 ± 1.0% modern**

A-266. Oracle, surface **20.2 ± 0.6% modern**

25 ft downslope from A-265, receiving more drainage.

Safford series, Arizona

Samples from road cut on Rte. 666 3 mi N of Rte. 86, S of Safford (32° 28′ N Lat, 109° 40′ W Long), Graham Co. Coll. 1961 and subm. by J. J. Sigalove.

A-262. 2 ft below surface **2.0 ± .8% modern**

A-263. 5 ft below surface **<1.4% (2 σ criterion)**

D. Caliche from San Francisco Volcanic Fields, Flagstaff, Arizona

Samples were collected from the exposed surface of flows of different volcanic stages, as described by Colton (1950), from oldest (Stage 1) to the youngest (Stage V) to compare the occurrence and C^{14} content. As expected, caliche was thickest on the oldest flows and contained the most C^{14} on the youngest flows. Coll. 1961 and subm. by P. E. Damon and J. J. Sigalove.

Merriam Flow series (Stage IV)

Collected on road to Grand Falls, alt 55 ft, ca. 2 mi from Merriam Crater

(35° 20′ N Lat, 111° 15′ W Long), Coconino Co. This flow is considered post-Pleistocene by Colton (1950).

A-259. Merriam, 9 in. below land surface, not directly beneath A-260 **73.5 ± 1.1% modern**

A-250. Merriam, surface. Surface coating on boulders lying on land surface **71.5 ± 1.1% modern**

Comment: on this and other quite young material of this type, an estimate of the duration of accumulation of the $CaCO_3$ (caliche) deposit and hence the age of the surface or flow may be calculated from the equation:

$$A_{ToT} = \frac{1}{\lambda t}\left(1 - e^{-\lambda t}\right),$$

and by making the assumption of a uniform rate of accumulation. A_{ToT} is the total activity in the accumulated layer, equal to the ratio, sample/modern (% modern ÷ 100); λ is the decay constant and t is the duration of the accumulation up to the present; or, in this case, the age of the Merriam Flow. Using $A_{ToT} = .72$, the "age" comes out 5600 yr, a plausible number. This calculation has not been used on the older caliches because the rate of accumulation is almost certainly not constant.

Cedar Ranch Road series (Stage III)

Samples from a road cut in Cedar Ranch Road in a Stage III flow (35° 30′ N Lat, 111° 40′ W Long), Coconino Co.

A-272. Top of caliche, 5 in. depth **36.3 ± 0.8% modern**

A-273. Bottom of caliche, 20 in. depth **12.1 ± 0.8% modern**

A-271. Stage II Flow **23.2 ± 1.0% modern**

Caliche from flow on top of Black Point flow along Rte. 89 (35° 40′ N Lat, 111° 30′ W Long), Coconino Co. Sample from 6 to 10 in. below surface, at top of the calichified zone, in which the caliche was coating and cementing the cinders.

Black Point Flow series (Stage I)

From road cut in Rte. 89 N of Flagstaff (35° 41′ N Lat, 111° 30′ W Long).

A-270. Black Point, top 2 ft below surface, top of calichified zone **14.0 ± .8% modern**

A-285. Black Point, boulder Caliche plate covering bottom of boulder; whole layer, ¾ in. thick **12.4 ± 1.0% modern**

A-286. Black Point boulder, outer ¼ in. of A-285 **14.5 ± 1.0% modern**

A-287. Black Point boulder, inner ¼ in. of A-285 **0.8 ± 0.5% modern**

Leupp Road series

Samples from road cut (35° 21′ N Lat, 111° 12′ W Long), Coconino Co. Exposed section consisted of two caliche zones, apparently of different ages. The lower zone, 18 in. thick, is in an old soil profile in a Stage I flow buried by cinders. The upper caliche zone is 2 in. thick in the cinder layer 2 ft below the land surface, 3.5 ft separate the two caliche zones.

A-277. Upper caliche zone **42.5 ± 1.0% modern**

A-278. Top of lower caliche **12.9 ± 1.0% modern**

A-279. Bottom of lower caliche **9.6 ± 1.0% modern**

VII. WATER SAMPLES

An apparatus has been built for the extraction of CO_2 from water, patterned after the one at the Physikalisches Institut, Univ. of Heidelberg (Vogel, written communication). Studies are now under way to measure residence times in ground-water reservoirs, travel rates in aquifers, and contamination of water by bomb-produced C^{14}. A rigorous interpretation of the ages will be withheld until the study is more advanced. Standard deviations reported include only counting uncertainty.

A-264. Tucson, Arizona **58.9 ± 1.4% modern**

Tap water sample from Geol. Bldg., Univ. of Arizona (32° 15′ N Lat, 110° 55′ W Long). Coll. 1961 and subm. by J. J. Sigalove.

A-292. Tucson, Arizona **60.4 ± 1.5% modern**

Tap water from Geol. Bldg., Univ. of Arizona (32° 15′ N Lat, 110° 55′ W Long). Coll. Feb. 3, 1962 and subm. by J. J. Sigalove.

A-317. Pinaleno Mountains, Arizona **92.4 ± 1.4% modern**

Water from Columbine Spring, alt 7500 ft, Mt. Graham (maximum alt, ca. 10,700 ft), Graham Co. (32° 35′ N Lat, 109° 51′ W Long). Water is from a perennial spring believed to be transported down the mountain through a series of fractures. Coll. 1961 and subm. by J. J. Sigalove.

A-320. Safford, Arizona **31.9 ± 2.4% modern**

Sample of warm water from a 1200-ft well S of Safford (32° 51′ N Lat, 109° 42′ W Long), Graham Co. Coll. 1961 and subm. by J. J. Sigalove.

Window Rock series, Arizona

Water samples were collected from a spring below the recharge area and from three wells in a ground-water system amenable to treatment by a mathematical model, from Window Rock (35° 45′ N Lat, 109° 5′ W Long), Apache Co. Coll. 1962 by J. J. Sigalove and H. H. Schumann; subm. by Sigalove. The recharge area, spring and wells are in the De Chelly and Coconino sandstones, Paleozoic aquifers, sandwiched by shales (Chinle above, Supai below).

A-344. Spring **84.7 ± 2.1% modern**

Located ca. 2 mi from the main recharge area at base of Chinle shale which overlies the aquifer. This spring represents the recharge into the Coconino formation, partly rejected here because of local geologic structure.

A-341. Morman Church well **45.7 ± 1.5% modern**

Alt 6955 ft, depth to water 23 ft, located ca. 3 mi from main recharge area.

A-342. St. Michael Chapter House well **54.1 ± 1.6% modern**

Alt 6800 ft, depth to water 37 ft, located ca. 4 mi from main recharge area, 0.7 mi from A-341.

A-343. Window Rock well **12.4 ± 1.7% modern**

Alt 6617 ft, depth to water is 83 ft, located ca. 5 mi from main recharge area, 1.4 mi from A-342.

VIII. MODERN ORGANIC SAMPLE

	δC^{14},‰	δC^{13},‰	Δ,‰
A-329. Tucson, Arizona	**310 ± 6**	**−22.4**	**303 ± 6**

Leaves from mulberry tree growing in residential area on outskirts of Tucson (32° 14′ N Lat, 110° 53′ W Long). Coll. May 20, 1962 and subm. by P. E. Damon. *Comment*: these leaves are from the same tree as L-523 (Lamont VIII) collected April 4, 1959. At that time $\Delta = 187 \pm 8$‰.

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