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Citations. A number of radiocarbon dates appear in publications without laboratory citation or reference to published date lists. We ask that laboratories remind submitters and users of radiocarbon dates to include proper citation (laboratory number and date-list citation) in all publications in which radiocarbon dates appear.

Radiocarbon Measurements: Comprehensive Index, 1950–1965. This index covers all published ^{14}C measurements through Volume 7 of *RADIOCARBON*, and incorporates revisions made by all laboratories. It is available at $25.00 per copy.

List of laboratories. Our comprehensive list of laboratories appears annually. We are expanding the list to include additional laboratories and scientific agencies with whom we have established contacts. The editors welcome more information on these or other scientific organizations. We ask all laboratory directors to provide their telephone, telex and fax numbers as well as their E-mail addresses. Changes in names or addresses, additions or deletions should also be reported to the Managing Editor.

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ASSOCIATE EDITORS

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FROM THE EDITORS

ACL - EAST

The Tucson conference is behind us and the Glasgow conference ahead. One item that will likely be on the agenda of the business meeting in Glasgow is the future of the Association of Carbon-14 Laboratories (ACL). Despite the fact that the only activities of this nascent organization are distribution of this journal to laboratories that have no access to US dollars and donations to colleagues to cover travel expenses to conferences, an overriding aversion to organizations within the radiocarbon community has thwarted endorsement. I hope that by the time of the Glasgow meeting, most will realize that the ACL poses no threat to their individuality or bank accounts, but that directors of the several ^{14}C laboratories that receive free copies of *RADIOCARBON* are genuinely grateful.

Meanwhile, during this interlude between International Radiocarbon meetings, according to a letter that some of us received from Professor J.-M. Punning, delegates from several Eastern European laboratories convened in Tallinn (November 1991) to form an Eastern European ACL. Their stimulus for creating this organization was the ACL discussions in Tucson. Their purpose in existence is stated below in six points:

1. Render mutual methodological air to its members in fundamental and applied scientific research
2. Exchange information about the scientific and methodological achievements of association members
3. Carry out calibrations in the form of exchange of standard and cross-check samples
4. Elaborate projects and provide peer reviews on them
5. Establish a regional data bank
6. Publish results of projects.

The Eastern European ACL will organize seminars and conferences, and will help with publication of collections and periodicals. Members will regularly exchange publications. The association will keep a list of addresses and personnel in all active ^{14}C laboratories in the region.

Membership will be contingent on acceptance by the Presiding Board and other members, and a yet unspecified annual fee will be accepted.

Promotion of these objectives can hardly be termed controversial, so I list them without further comment. It may be useful, however, to discuss the relationship between the neophyte ACL discussed in Tucson, and the ACL newly formed in Tallinn. I welcome your comments.

Austin Long

A VIEW FROM THE WEST

I feel compelled to describe the events surrounding the development (?) of the Association of Carbon-14 Laboratories (ACL), from June 1988 to the present. It all started as Austin Long and I sat in the Secretariat of the Dubrovnik Palace Hotel and discussed ideas for offering the next conference in Tucson. I remember saying, "What we need is an organization to raise funds for travel expenses for those who do not have access to hard currency." Austin thought that was a fine idea, and said he would discuss it with Wim Mook, who should announce it at the Business Meeting.

We were disappointed that the proposal did not meet with too much enthusiasm, but we thought that the time was premature and further discussions were needed. Wim threw himself into the project with much energy and effort, and we, at *RADIOCARBON*, joined him. In April 1989, Wim visited Tucson, where we talked about the goals and functions of the ACL. These were:

1. Communication
2. Technical cooperation
3. Projects (such as conferences or workshops, publications)
4. Bringing together small, isolated laboratories
5. Sponsoring subsidized issues of *RADIOCARBON*
6. Fundraising for special projects (such as the IRDB)
7. Quality certification

Through our combined efforts, six laboratories have been receiving free subscriptions to *RADIOCARBON* for three years. The ACL also contributed $2500 to the 14th International Radiocarbon Conference to cover travel expenses for colleagues who could not manage to attend without our help. Some laboratories have agreed to join this noble effort by contributing the cost of dating one sample per year. To date, the ACL has contributed about $3500 to the radiocarbon community.

Wim's presentation in Tucson was greeted with less than optimism. Nonetheless, a committee was selected to prepare the way for officially establishing the ACL. Members of this committee met after the Business Meeting, but we have not heard of any results.

If *RADIOCARBON* is to be a vehicle of communication among the radiocarbon community, I recommend a discussion of this project in its pages. Three years between meetings, with no general discussions during the interval, is too long to accomplish any goals. If we are to wait for Glasgow to vote on the fate of the ACL, on the last day of the conference, with no discussions beforehand, we will not succeed.

The new ACL-East (this is our own, unofficial title) sets a good example for us to follow. The six points with which Austin Long has summarized their objectives indicate the urgent need for such an organization. I congratulate J.-M. Punning for his aggressive approach to the formation of this organization. Not only has the Presiding Board been elected, but also the by-laws have been drafted. Perhaps the Committee appointed at the Business Meeting of the Tucson conference should follow suit and call a workshop well before the Glasgow conference to discuss and implement, once and for all, the establishment of the ACL.

Your thoughts on the matter are more than welcome.

Renee Kra

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Radiocarbon

1992

ISOTOPE DATING OF PLEISTOCENE DUNG DEPOSITS FROM THE COLORADO PLATEAU, ARIZONA AND UTAH

JIM I. MEAD[1] and LARRY D. AGENBROAD

Department of Geology and Quaternary Studies Program, Box 6030, Northern Arizona University Flagstaff, Arizona 86011 USA

ABSTRACT. Identified dung and keratinous remains of large mammals are considered the most reliable materials to ^{14}C date, when the initial question includes the application of the date to the time of local extirpation and extinction. The Colorado Plateau provides a unique preservation habitat (desiccation), found in greater abundance of deposits than anywhere else in North America. We review 20 localities from the Colorado Plateau that contain dung of megaherbivores. Seven species of herbivores were identified utilizing dung: *Bison* (bison), *Equus* (horse), "*Euceratherium*" (shrubox), *Mammuthus* (mammoth), *Nothrotheriops* (ground sloth), *Oreamnos* (mountain goat) and *Ovis* (bighorn), and 79 ^{14}C dates were measured from the sites. Most sites contain additional associated ^{14}C and U/Th dates on skeletal and botanical remains.

INTRODUCTION

This article is about ^{14}C dating of dried dung recovered from alcoves and caves on the Colorado Plateau of Arizona and Utah. Beyond the significance of the dung as a paleontological curiosity, the broader issue is that these remains provide high-quality organic residues for ^{14}C results. When the dung is identified to the generic or specific level, the perishable remains become a valuable tool for exploring the timing and possibly the reasons for late Wisconsin extinctions and extirpations in southwestern USA. Dung contents of extinct Pleistocene herbivores are found predominately in two regions: Holarctic permafrost (*e.g.*, Siberia and Alaska), or dry caves in Southwest USA (although portions of Mongolia, China and Australia might also be included in the near future). Large and small animals enter shelters, such as alcoves and caves, for a variety of reasons. During the time of their stay within the shelter, the animals often leave behind tissue remains (hair and keratin), or they may die, leaving muscle, hide and bone. More often, they will deposit dung. The arid environment outside of, and the hyperarid situation within the shelter that has persisted for more than 40 ka, preserves the organic remains by desiccation or extreme dehydration.

Although often common when found in a particular site, dung deposits are unusually rare in the Southwest. Desiccated Pleistocene dung has been found in caves in the Basin-and-Range regions of Arizona, Nevada, New Mexico, Texas and Utah. The deposits are small and the localities are few, compared to the shelters that have been studied on the Colorado Plateau, mostly since 1983 (Fig. 1). The dry, flat-lying Paleozoic and Mesozoic sedimentary formations of northern Arizona, eastern Utah, western Colorado and northwestern New Mexico have provided a unique setting for caves and alcoves that have preserved numerous late Pleistocene (upper Rancholabrean, terminal Wisconsin Glacial) organic deposits.

[1]Also, San Bernardino County Museum, Redlands, California 92374 USA

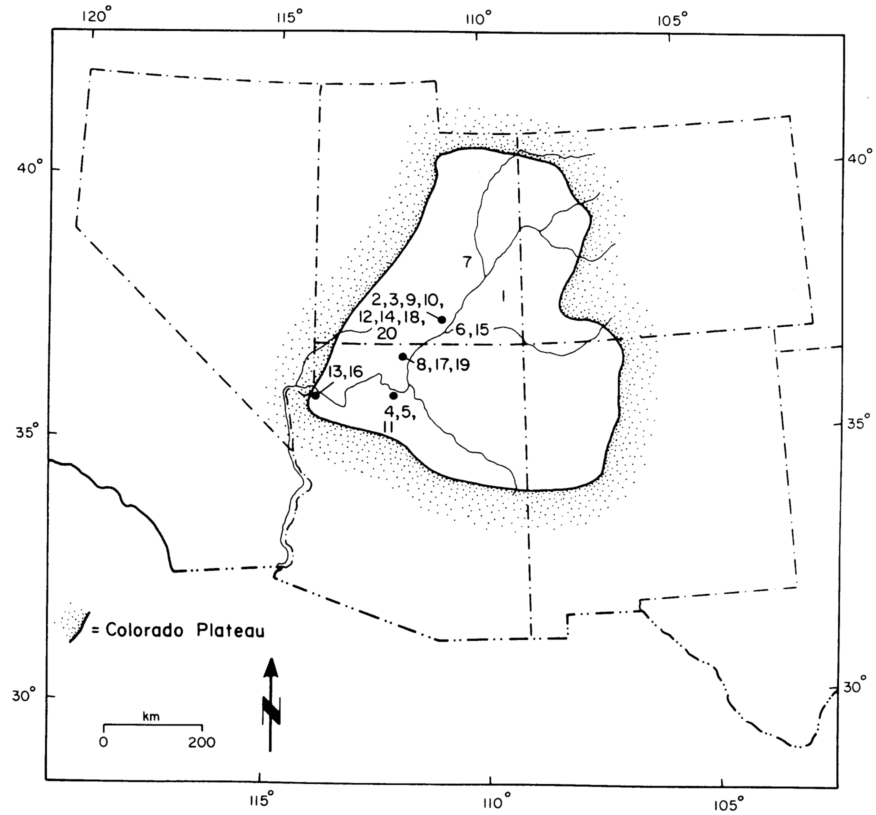

Fig. 1. Map of the Colorado Plateau illustrating general locations of sites discussed in the text

Dried dung has largely gone unappreciated for its potential accuracy of ^{14}C analysis and availability of other data resources. Few remains of animals are more critical to ^{14}C dating for the purpose of succinctly analyzing a species of extinct megaherbivore than the specimens of identifiable and preserved dung (Meltzer & Mead 1985). Analysis of dung deposited by extinct or extirpated megafauna in the Southwest began with Lull's (1930) description of the ground sloth (*Nothrotheriops*) boluses found in Rampart Cave, Grand Canyon National Park. But not until Martin, Sabels and Shutler's (1961) detailed examination of the dung deposits for clues to megafaunal extinction, did the analysis of feces become an integral part of paleoecological reconstructions in the arid Southwest.

Paramount to the usefulness of Pleistocene dung is the identification of the producer. The more unusual morphologies are readily identifiable. Martin, Sabels and Shutler (1961) have provided criteria for the identification of *Nothrotheriops shastensis* (Shasta ground sloth) dung boluses. The unusually large contents and overall size of elephant dung, such as *Mammuthus* (mammoth), is characterized in Hansen (1980), Davis *et al.* (1984) and Mead *et al.* (1986a).

The pellet-producing herbivores provide problematic identifications. Cervids (deer) and most bovids (cattle, sheep, *etc.*) produce pellets of dung with little apparent morphological differences. Large cuboid pellets recovered from caves in the Grand Canyon were identified as *Oreamnos harringtoni* (Harrington's mountain goat), following the criteria in Robbins, Martin and Long (1984) and Mead, O'Rourke and Foppe (1986). These large pellets are typically found in caves in rough terrain, associated with skeletal remains of only *O. harringtoni.* The sandstone alcoves in the Glen Canyon and Canyonlands regions north of the Grand Canyon are in less rugged terrain, permitting additional less agile pellet-producing species to use the same shelter as *Oreamnos*. Here, the identification of the pellet producers is less reliable. Because of this problem, Mead, Theis and Agenbroad (ms.) are now developing criteria using nuclear magnetic resonance (NMR) of bile acids to provide a biochemical "signature" for identifying the various dung morphologies.

A large dung pellet (significantly larger than that of *Oreamnos harringtoni*) is being recovered consistently from the easily accessible sandstone shelters in Utah. These pellets were found in loose association with a tooth of *Euceratherium collinum* (shrubox), the only skeletal remains of a large mammal found during the excavation in Bechan Cave. These large pellets have an external morphology similar to the pellets of *Ovibos moschatus* (living muskox) and *Symbos* (extinct muskox; frozen carcass remains). In this article, we refer these unique pellets to "*Euceratherium*," until our NMR results are final.

Here we provide a review and update of radiocarbon-dated dung remains and their localities on the Colorado Plateau, reported in a wide array of publications by various researchers since 1961. We collected and studied the material at 15 of the 20 localities published about the Colorado Plateau. An asterix (*) in front of the locality name indicates the sites at which one or both of us have investigated the organic remains. The number preceding the asterix provides the numbered location in Figure 1.

Many of the sediments forming the loose-to-weakly compacted alcove fill are derived from eolian deposition, evaporite crystal exfoliation and cliff spall clasts. Excavation of these sites without a great deal of broadside digging and shoring is often prohibitive in the loose sediments, due to slumpage. Thus, we usually removed material on the exposed erosional slope angle (Fig. 2). These deposits are relatively loose, with an angle of repose of ~30° to 36°. Once a particular organic unit was found, its *in-situ* position was verified by limited test excavation and its remains collected. We recorded dung (and other organic specimens) by depth below the horizontal surface of the deposit in the shelter. The dated samples included here are all plant tissues removed from the dung of extinct herbivores, and as such, provide a tight temporal association between herbivore producer, plant species ingested and local floral community. All dates are reported in years before present (BP) (AD 1950), using the Libby half-life of 5568 years.

Most of the published dung sites are on lands administered by the National Park Service (NPS). This agency has indicated that, in order to help protect these deposits, we should not locate the sites on a map. Figure 1 is a generalized map illustrating the approximate location of the dung sites discussed in the text. This map is solely for an overall appearance of the locations. The sensitivity of these dry dung sites by us and the NPS is justified in view of the 1976 destruction by fire of the organic layers in Rampart Cave, Grand Canyon. This sort of needless ruin of non-renewable fossils must not happen again. Any researcher desiring exact location data should contact the Regional Scientists of either the Rocky Mountain or Western regional offices of the NPS. Locality and NPS accession numbers are indicated for many sites, usually those containing materials curated into the NPS Repository at the Laboratory of Quaternary Paleontology, Quaternary Studies Program, Northern Arizona University, Flagstaff.

We use the following abbreviations: BLM – Bureau of Land Management; GLCA – Glen Canyon National Recreational Area; GRCA – Grand Canyon National Park (GCNP, an old designation still used with some of the older curated material); NPS – National Park Service; NABR – Natural

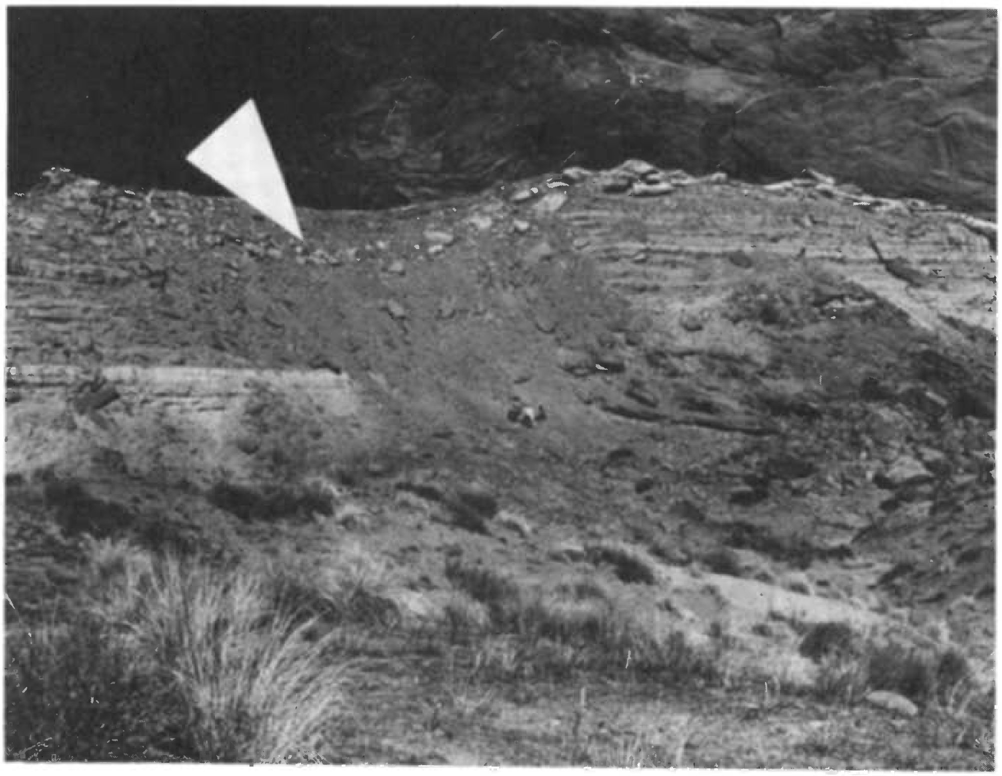

Fig. 2. Grobot Grotto. Note people in middle for scale of deposit. Stratified fluvial units in the lower sections of the profile are dating to the Sangamonian Interglacial, based on thermoluminescence (TL) analyses. Stratified eolian and spall sediments containing macrobotanical and dung remains occur immediately below and predominantly above the large rockfall "smile" (see arrow) in the upper portion of the picture. Beta-14422 lies immediately below and touching the large rockfall, smile, layer.

Bridges National Monument; and QSP – Quaternary Studies Program, Northern Arizona University. Laboratories include: A – Arizona; AA – Arizona Accelerator; Beta – Beta Analytic Inc.; GX – Geochron Laboratories; L – La Jolla; RL – Radiocarbon Limited.

1. * **Bare Ladder Shelter**

This alcove (NAU QSP site 8710; NPS NABR) is located in the Cedar Mesa Sandstone at 1830 m elevation (10 m above the present alluvial terrace), White Canyon, Natural Bridges National Monument, Utah. Remnant deposits including dung and packrat middens are common in the protected crevices in the back of the wide shelter (Mead *et al.* 1987). Dung and packrat midden data, reported here, come from a 100-cm profile. Although in entire pellet form, the dung was becoming friable in the lower level, and thus was not pretreated with NaOH. Twenty pellets from each unit were measured and cut in half; 20 halves were used for dating; the other halves were used for microhistology. Mead *et al.* (1987) provide measurements and microhistological data from the dung pellets.

GX-11312. Oreamnos harringtoni **>39,800**

Pellets from Layer 0, basal level in the 100-cm profile. $\delta^{13}C = -25.2‰$

GX-11313. Oreamnos harringtoni **23,350 $^{+1740}_{-1430}$**

Pellets from Layer 2. $\delta^{13}C = -26.0‰$

Comment: Additional ^{14}C dates from the site include a birch (*Betula*) twig (GX-11594, 26,470 +740/−680; assumed to be an introduced contaminant) and packrat middens (Layer 3, Beta-14418, 21,330 ± 240; Layer 5, Beta-14419, 9660 ± 160).

2. * **Bechan Cave**

Bechan Cave (NAU QSP site 872; NPS GLCA Accession 81) is a large sandstone grotto at 1280 m elevation. The single-room cavern is ~52 m long, 31 m wide and 9 m high. With a southwest-facing entrance, the room stays well lit during the daytime. Numerous test excavations, corings and analyses were made to determine the morphology and character of the dung deposit (Agenbroad *et al.* 1989; Davis *et al.* 1984, 1985; Martin 1987; Mead & Agenbroad 1989; Mead *et al.* 1984, 1986a).

The upper unit of the deposit contains a layer of roof spall and eolian sand mixed with cultural materials (Agenbroad *et al.* 1989). Sand comprises the lowest unit tested. The middle unit is a layer of organic remains, composed predominantly of dung, mostly derived from the mammoth (*Mammuthus columbi*). Most of the large dung is fragmented, however, several entire boluses and numerous plant remains are common. Initially, it was assumed that whatever was recovered from the dung unit must have been part of a mammoth bolus and thus a segment of its diet (Davis *et al.* 1984, 1985). Subsequently, we have determined that at least eight different dung morphologies can be recognized in the organic unit, including the following: cottontail rabbit (*Sylvilagus*), mammoth, shrubox ("*Euceratherium collinum*"), packrat (*Neotoma*), Shasta ground sloth (*Nothrotheriops shastensis*), bighorn sheep (*Ovis canadensis*), *cf.* mountain goat (*Oreamnos harringtoni*) and possibly, horse (*Equus*).

A-3212. *Mammuthus* **11,670 ± 300**

Fragment of M1 bolus. $\delta^{13}C = -23.2‰$

A-3213. *Mammuthus* **12,900 ± 160**

Fragment of M2 bolus. $\delta^{13}C = -23.2‰$

A-3296. *Mammuthus* **11,850 ± 160**

Fragment of M3 bolus. $\delta^{13}C = -25.7‰$

12,400 ± 250

A-3297. *Mammuthus* $\delta^{13}C = -21.9‰$

Predominantly mammoth dung fragmented bolus, but possibly also contains other organic remains.

A-3298. *Mammuthus* **12,620 ± 220**

Fragment of M4 bolus. $\delta^{13}C = -18.4‰$

The following 14 samples are single plant remains removed by O. K. Davis and P. S. Martin, Desert Laboratory, The University of Arizona, Tucson, from single mammoth dung boluses or bolus fragments that we collected during our initial excavation. AA samples were dated using accelerator mass spectrometry (AMS) by the NSF-Arizona Facility for Radioisotope Analysis.

AA-1109. Grass culms **12,470 ± 140**

AA-1110. *Atriplex* **12,390 ± 120**

AA-1111. Grass culms **13,040 ± 280**

AA-1112. *Atriplex* **12,430 ± 300**

AA-1113. Grass culms **12,090 ± 210**

AA-1114. Sedge achenes **12,320 ± 160**

AA-1116. Grass culms **12,610 ± 140**

AA-1117. *Atriplex* **12,620 ± 130**

AA-1119. Grass culms **12,430 ± 150**

AA-1120. Grass culms **12,880 ± 140**

AA-1121. *Atriplex* **12,570 ± 130**

AA-1122. Sedge achenes **12,390 ± 140**

AA-1123. Grass culms **11,870 ± 140**

AA-1124. *Atriplex* **12,570 ± 100**

Beta-18269. "*Euceratherium*" **11,630 ± 150**

A spring-green mass containing pellet forms.

GX-9371. *Mammuthus* **13,505 ± 580**

A fragmented bolus with possibly other organic remains.

Comment: A dated twig of oak (*Quercus*) recovered loose from the organic unit indicates that the plant remains were deposited before the beginning of most of the megafaunal dung deposit (A-3514, 16,700 ± 250, Davis *et al.* 1985).

3. * **BF Alcove**

BF Alcove (NAU QSP site 877; NPS GLCA Accession 82) faces north at 1204 m elevation, with a wide shelter entrance containing a narrow (8 m) deposit preserved within the dripline (72 m above modern streambed base level). Most of the alcove is filled with laminated fluvial sediments, overlain by a thin veneer of dry eolian loose sand at the top (8 by 16 m). Douglas fir (*Pseudotsuga* *menziesii*) needles and maple (*Acer* spp.) were associated with two dung pellets that appear to be as large as a camel's (*Camelops*). No dates were directly measured on the dung pellets. Beta-14727, 11,790 ± 190, dates Douglas fir and maple needles and seeds; another Douglas fir sample (Beta-20995) dates to 12,130 ± 170 BP. Withers (1989) and Withers and Mead (ms.) discuss these plant remains.

4. * **Bida Cave**

Bida Cave (NAU QSP site 919; NPS GRCA Accession 4597) is a limestone grotto with a large lower entrance room at 1430 m elevation, containing numerous surface remains of the extinct mountain goat (*Oreamnos harringtoni*). Cole (1981, 1982, 1990) and Cole and Mead (1981) discussed the packrat middens recovered from the cave. Test-pit excavations yielded a multitude of faunal and floral remains. Mead *et al.* (1986b) discussed the ^{14}C dates of the hornsheaths of the extinct Harrington's mountain goat.

A-2373. ***Oreamnos harringtoni*** **$24{,}190^{+4300}_{-2800}$**

Four dung pellets from Layer 8 in test pit 9N00 were measured for identification and then sectioned for ^{14}C dating and microhistological (dietary) content analyses.

RL-1133. ***Oreamnos harringtoni*** **13,100 ± 700**

Dung pellets were recovered on the surface next to the skull of *O. harringtoni* (GCNP 21974). The hornsheath from the skull dated to 12,930 ± 110 (SI-3988). Pellets were measured for identification and then sectioned for ^{14}C dating and microhistological content analyses.

RL-1134. ***Oreamnos harringtoni*** **11,850 ± 750**

Dung pellets were removed from a ground depression used for sleeping located on the surface at the back of the entrance room adjacent to the point of total darkness (Mead 1983). Pellets were measured for identification and then sectioned for ^{14}C dating and microhistological content analyses.

RL-1135. ***Oreamnos harringtoni*** **16,150 ± 600**

Pellets were removed from Layer 4 in test pit 9N00. Pellets were measured for identification and then sectioned for ^{14}C dating and microhistological content analyses.

5. * **Chuar Cave**

Chuar Cave is an inadequately understood cave in GRCA.

Beta-28791. ***Oreamnos harringtoni*** **29,380 ± 990**

Pellets and amalgamated dung mat layer.

6. * **Cottonwood Alcove**

Cottonwood Alcove (our name for archaeological site 42SA20858; GLCA) measures 160 m by 15 m on a south-facing aspect (75 m above the present streambed), and is located at 1195 m elevation. This sandstone alcove was visited in the late 1980s by archaeologists on a survey of Anasazi cultural remains. The surface area of the alcove contains large dung pellets eroding out of the talus slope, similar to that found in Grobot Grotto and Hooper's Hollow (see below), and in sediments removed by the Anasazi and tossed down the slope. The site has not been excavated or tested (P. Geib, personal communication). Isolated dung pellets were collected by Phil Geib, Northern Arizona University, and given to us for ^{14}C and morphometric analyses.

Beta-28790. "*Euceratherium*" **12,510 ± 190**

Parts of two pellets, halved after measurements; 0.5 gm C was given extended counting time.

7. **Cowboy Cave**

Cowboy Cave is a large single-room grotto in sandstone on land administrated by the BLM. Most of its sediments contain archaeological material of Archaic age, however, the lowest layers contain Pleistocene dung. Jennings (1980) described five sedimentary units in the cave, the lowest (I) divided into two subunits. ^{14}C ages range from 13 to 0.5 ka BP. Unit Ib is an organic mat similar to that found in Bechan Cave, but composed predominantly of *Bison* (not *Mammuthus*) dung. Hansen (1980: 182) ascribed the fragmented remains of dung to both living and extinct species of late Pleistocene megafauna – elk, elk-camel, elephant, horse, and Shasta ground sloth. Many of these remains are being reanalyzed by nuclear magnetic resonance.

A-1653. Herbivore **12,070 ± 210**

This dung sample is unidentified, but it is probably disaggregated *Bison* dung boluses. It was collected by associates at the Desert Laboratory, The University of Arizona.

A-1654. Herbivore **13,040 ± 440**

See description of A-1653, above.

A-1800. Herbivore **12,320 ± 160**

See description of A-1653, above.

UGa-636. Herbivore **11,810 ± 140**

See description of A-1653, above. This sample was collected during preliminary excavations (Jennings 1980).

8. * **Disappearing Cave**

Disappearing Cave is a small limestone shelter opening out onto the Marble Canyon region of GRCA. Much of the entrance area is exposed and eroding. A small stratified section of sediments, plant remains and dung pellets is still in existence.

Beta-28792. *Oreamnos harringtoni* **27,360 ± 960**

Dung pellets were removed from the surface of a mat unit.

9. * **Grobot Grotto**

Grobot Grotto (NAU QSP site 878; NPS GLCA Accession 82) is a south-facing shelter at 1189 m elevation. This large alcove (Fig. 2) consists of 6 m of stratified eolian sand and roof spall with interspersed layers of dung and leaf-litter matting. Because of the extremely loose sand units, the stratified units were not formally excavated, although the layers on the slope exposure have been studied in detail (Withers 1989; Withers & Mead, ms.). Numerous coprolite remains are known from the site, but only *Mammuthus*, *Bison* and "*Euceratherium*" were dated directly. *Cf. Ovis* and *cf. Oreamnos* were also dated by association with the ^{14}C dates. Overlying Holocene units yielded the following ^{14}C ages: Beta-20997: 9920 ± 100, wood; Beta-20998: 9730 ± 170, wood, 0.5 gm C used for extended counting; Beta-20999: 7510 ± 160, wood 0.4 gm C used for extended counting (Withers 1989; Withers & Mead, ms.).

Beta-14420. "*Euceratherium*" **20,930 ± 400**

Isolated pellets from on the slope of the profile.

Beta-14422. *Mammuthus* **28,290 ± 2100**

A dung bolus from the slope.

Beta-20996. *Mammuthus* **26,140 ± 670**

A dung bolus from slope depth, 10.1 m. 0.7 gm C used for extended counting.

Beta-22999. *Bison* **15,270 ± 120**

A single bolus from slope depth, 3 m.

Beta-23322. "*Euceratherium*" **18,320 ± 290**

Pellets from slope depth, 3.48 m.

10. * **Hooper's Hollow**

Hooper's Hollow (NAU QSP site 873; NPS GLCA Accession 82) is a wide, south-facing alcove at 1204 m elevation, just upstream from Grobot Grotto (Agenbroad & Mead 1987). Typical of the canyon, laminated fluvial sediments choke most of the alcove, and eolian material and cliff spall comprise the upper 2–4 m of deposit. Many organic layers lie within these upper units. Other ^{14}C dates derived from the upper deposits include a packrat midden (Beta-23710: 13,110 ± 100) and oak twigs (Beta-25412: 10,630 ± 110; Beta-25411: 12,010 ± 110). In addition to the dated *Bison* dung, "*Euceratherium*" and *cf. Ovis* are dated by association. A single bone element of *Oreamnos harringtoni* was recovered from a deflated and unprovenienced locus at the site. More detailed analysis of the stratified units and their contents are needed.

Beta-23323. *Bison* **18,840 ± 350**

This sample is from a single, large, complete dung bolus of pie consistency and shape. Mead and Agenbroad (1989) provide dietary data.

11. * **Kaetan Cave**

This site (NAU QSP site 9117; NPS GRCA Accession 4597) is a medium-sized limestone cave at 1430 m elevation with an eastern orientation. The deposit in the cave was first excavated for split-twig figure archaeology (Schwartz, Lange & DeSaussure 1958). Mead (1983) excavated portions of the deposit in the entrance room for remains of *Oreamnos harringtoni* (Mead, O'Rourke & Foppe 1986; O'Rourke & Mead 1985). McVickar and Mead are preparing a manuscript on paleoenvironmental reconstruction based on macrobotanical remains recovered from packrat middens and stratified sediments of this site.

A-2371. *Oreamnos harringtoni* **18,290 ± 1400**

Surface sample, composite of 10 pellet halves.

A-2722. *Oreamnos harringtoni* **30,600 ± 1800**

Level 6 in test pit 1, matted dung layer with some whole pellets.

A-2723. *Oreamnos harringtoni* **17,500 ± 300**

Level 3 in test pit 1, matted dung layer with many whole pellets.

A-2835. *Oreamnos harringtoni* **14,220 ± 320**

Level 1 in test pit 1, whole pellets isolated in sediments.

12. * **Mammoth Alcove**

Mammoth Alcove (NAU QSP site 875; NPS GLCA Accession 82) is a medium-sized shelter, contained in a perched, bedrock meander bend. Like the other shelters, Mammoth Alcove, at 1188 m elevation on a south-southeast exposure, contains laminated lacustrine and fluvial sediments characteristic of other canyon alcoves. At the base of this sedimentary sequence, we recovered the remains of a mammoth skeleton. We also recovered dung boluses of *Mammuthus*, *Bison*, and *cf. Ovis* overlying the skeleton, in the eolian and roof spall units.

Beta-20705. *Mammuthus* **16,630 ± 280**

This sample is a portion of a larger mammoth dung bolus fragment that was deflating out of loose-to-slightly compacted sand at the horizontal surface in the alcove. We feel that this date is stratigraphically correct.

Comment: The whole bone fraction of mammoth bone was dated (Beta-20704, 10,505 ± 260). We believe that the date is erroneous, based on inherent problems with whole bone fraction dates, and the dung date (Beta-20705), recovered well above the skeleton. A vertebra from the same skeleton was dated by U/Th: 19,300 ± 600 (Richard Ku, University of Southern California). The sample had a low ^{232}Th concentration, and thus, a large ^{230}Th/^{232}Th ratio. We did not obtain a ^{231}Pa/^{235}U cross-check analysis; however, we assume that this U/Th date is correct and reject Beta-20704, the ^{14}C date.

13. **Muav Caves**

These caves (GRCA) are a series of three small north-facing solution tubes in the Muav Limestone, at 426 m elevation, which coalesce with their sedimentary floor deposits at their entrances. Sporadic examinations were made and test pits dug, but no formal excavation was made. Most analyses have centered on the *Nothrotheriops* dung (Long & Martin 1974; Long, Hansen & Martin 1974; Martin, Thompson & Long 1985; Mead & Agenbroad 1989). Specimens of the dung are stored at the Department of Geosciences, The University of Arizona. All samples were apparently recovered from the surface.

A-1212. *Nothrotheriops shastensis* **11,140 ± 160**

Single dung bolus.

A-1213. ***Nothrotheriops shastensis*** **11,290 ± 170**

Single dung bolus.

A-2625. ***Nothrotheriops shastensis*** **11,610 ± 60**

Single dung bolus.

A-2626. ***Nothrotheriops shastensis*** **10,650 ± 220**

Single dung bolus.

A-2627. ***Nothrotheriops shastensis*** **11,060 ± 240**

Single dung bolus.

A-2628. ***Nothrotheriops shastensis*** **11,810 ± 70**

Single dung bolus.

14. * **Oak Haven**

Oak Haven (NAU QSP site 881; NPS GLCA Accession 82) is a small shelter at 1188 m elevation with a north-northwest aspect, directly across from Mammoth Alcove. The site contains the remnants of stratified layers. Collected near the surface, a sample of *Quercus gambelii* was ^{14}C dated to 9180 ± 100 (Beta-28929), with *Rosa woodsii* twigs, a unit below, to 11,690 ± 120 (Beta-25418). Between the *Quercus* and the *Rosa* were dung of *Mammuthus*, *Bison* and "*Euceratherium*"; although all were dated by association, each species could be, and should be, dated directly. Withers (1989) and Withers and Mead (ms.) have studied the plant macrofossils; however, the site needs more detailed study. This site is included in this list to indicate that material is available for future detailed ^{14}C analysis.

15. **Oakleaf Alcove**

Oakleaf Alcove is in Lake Canyon, 0.4 km up-canyon from the original confluence with the Colorado River, and is now submerged under Lake Powell (GLCA). The shelter (archaeological site 42SA374) was heavily vandalized prior to the archaeological survey and testpit analyses in the early 1960s. Martin and Sharrock (1964) reported on human coprolites from various shelters, including Oakleaf Alcove. The single *Equus* (horse) bolus was analyzed for pollen (200 grain count; 43% *Betula* and 39% *Artemisia*) and was ^{14}C dated (see A-526, below; Haynes, Damon & Grey 1966). Martin (personal communication 1990) indicates that the identification of the bolus as *Equus* is a best-estimate based on the level of identification of Pleistocene dung during the early 1960s. The specimen was so similar to horse dung, there was some doubt that it was a fossil. The ^{14}C analysis consumed the entire sample. Our experience is that the only other animal that would produce a bolus similar in appearance to a horse is *Nothrotheriops*, assuming that the horse dung contents were browse remains. The sloth is an unlikely candidate, given the local topography in the region of the alcove. Sometimes highly fragmented *Mammuthus* dung appears vaguely similar to a graze-diet horse bolus.

A-526. ***Equus*** **24,600 ± 1400**

A single bolus of dung.

16. **Rampart Cave**

Rampart Cave (NAU QSP site 9128; NPS GRCA Accession 4597) is a small limestone cave at 525 m elevation with a north-facing entrance. The deposit was discovered and test pits excavated in the 1930s. A trench was dug in 1941. Publications about this site include reports on the faunal remains (Wilson 1942), *Nothrotheriops shastensis* dung (Hansen 1978; Long, Hansen & Martin 1974; Laudermilk & Munz 1938; Long & Martin 1974; Martin, Sabels & Shutler 1961; Martin, Thompson & Long 1985; Thompson *et al.* 1980), *Oreamnos harringtoni* (Mead 1983; Mead *et al.* 1986b), and packrat middens (Phillips 1977, 1984; Phillips & Van Devender 1974; Van Devender, Phillips & Mead 1977). In 1976, fire destroyed all but a small section of the deposit. Faunal remains (skeletal, hide/hair, keratin and dung) can be found at the Department of Paleobiology, Smithsonian Institution, Washington, DC, the Desert Laboratory, The University of Arizona and in the GRCA collection.

A-1041. ***Nothrotheriops shastensis*** **11,480 ± 200**

Trampled dung mass from 0–5 cm depth.

A-1042. ***Nothrotheriops shastensis*** **>40,000**

Bolus from 132 cm depth.

A-1043. ***Nothrotheriops shastensis*** **36,200 ± 6000**

Bolus from 99 cm depth.

A-1066. ***Nothrotheriops shastensis*** **11,000 ± 140**

Bolus from the surface.

A-1067. ***Nothrotheriops shastensis*** **10,780 ± 200**

Bolus from the surface.

A-1068. ***Nothrotheriops shastensis*** **11,020 ± 200**

Bolus from the surface.

A-1070. ***Nothrotheriops shastensis*** **12,440 ± 300**

Bolus from 61 cm depth.

A-1207. ***Nothrotheriops shastensis*** **13,140 ± 320**

Bolus from 67 cm depth.

A-1210. ***Nothrotheriops shastensis*** **32,560 ± 730**

Bolus from 99 cm depth.

A-1278. ***Oreamnos harringtoni*** **18,430 ± 300**

Pellets from 91 cm depth. Eight keratinous hornsheaths of the extinct mountain goat from various levels were dated by AMS; ages span 10,140 to 28,700 (Mead *et al.* 1986b).

A-1318. ***Nothrotheriops shastensis*** **12,470 ± 170**

Bolus from an unknown location; possibly the same as sample I-442, but the date does not verify this.

A-1392. ***Nothrotheriops shastensis*** **11,370 ± 300**

Trampled bolus at 0–5 cm depth.

A-1395. ***Nothrotheriops shastensis*** **11,160 ± 130**

Bolus from an unknown location.

A-1453. ***Nothrotheriops shastensis*** **11,140 ± 250**

Bolus secondarily deposited into a packrat midden.

A-1602. ***Nothrotheriops shastensis*** **11,090 ± 190**

Bolus from the surface, unprovenienced location.

A-2174. ***Nothrotheriops shastensis*** **10,500 ± 180**

Bolus from an unknown location.

I-442. ***Nothrotheriops shastensis*** **10,400 ± 275**

Bolus from the surface, unknown location.

L-473A. ***Nothrotheriops shastensis*** **10,035 ± 250**

Trampled bolus at 0–5 cm depth. Martin, Thompson and Long (1985) suggest *Neotoma* contamination of this "young" sample.

L-473C. ***Nothrotheriops shastensis*** **12,050 ± 400**

Bolus from 46 cm depth.

17. * **Sandblast Cave**

Sandblast Cave (GRCA) is a series of three caverns that merge together to form a small cave complex. Locality A contains packrat middens and *Gymnogpys* bones and nesting materials (Emslie 1987, 1988). Locality B is a profiled fissure fill of sediments containing stratified layers of dung.

Beta-28793. ***Oreamnos harringtoni*** **>33,100**

Dung pellets from layer 1. 0.2 g of C was recovered from the pellets and were given extended counting time.

Beta-28794. ***Oreamnos harringtoni*** **>29,900**

Dung pellets from layer 3. 0.6 g of C was recovered from the pellets and were given extended counting time.

18. * **Shrubox Alcove**

Shrubox Alcove (NAU QSP site 882; NPS GLCA Accession 82) faces north-northwest at 1204 m elevation. The dripline is such that very little width of the deposit is preserved in this wide shelter. Overlying the laminated lacustrine and fluvial units are eolian and roof spall layers, where *Quercus* and dung pellets of "*Euceratherium collinum*" have been recovered. Oak twigs were dated (from bottom to top): Beta-25413: 23,100 ± 660 (1 twig); Beta-25416: 12,690 ± 180 (2 twigs, 0.5 gm C, associated with *Bison*, "*Euceratherium*", and *cf. Ovis* dung), and Beta-25656: 8830 ± 190 (0.25 gm C, with associated *Mammuthus*). Withers (1989) and Withers and Mead (ms.) provided paleobotanical and paleoenvironmental data. Dung samples of "*Euceratherium*," *Bison, Oreamnos, Ovis* and *Mammuthus* have been identified from this site, but not dated.

19. **Stanton's Cave**

Stanton's Cave (NAU QSP site 9121; NPS GRCA Accession 4597; archaeological site Ariz. C:5:3) is a large solution cavern in the Redwall Formation of the Grand Canyon (Euler 1984). The cave, at 927 m elevation, is 44 m above the present river level and has an eastern aspect. An archaeological excavation in the late 1960s for the split-twig figurines uncovered voluminous Pleistocene floral and fauna remains. Stratified sediments traverse the Holocene to the Holocene/Pleistocene boundary. Presently, *Ovis canadensis* lives in the area, as it apparently did throughout the Holocene. Initial studies of the stratified sediments containing dung pellets considered the "small pellets" to be from *Ovis* and the "large pellets" from the extinct *Oreamnos harringtoni* (Robbins, Martin & Long 1984). No "large pellets" were found above the 20-cm level in the stratified section. The identifications below are based on conclusions in Robbins, Martin and Long (1984) and Mead, O'Rourke & Foppe (1986). Euler (1984) includes numerous articles on various aspects of the cave and its contents. Mead *et al.* (1986b) present AMS dates of the hornsheaths of *Oreamnos* (n = 15), and Mead *et al.* (1991) offer AMS dates and stable carbon/nitrogen isotope ratios of *Ovis* (n = 3) and *Oreamnos*. We curated most of the skeletal remains for the NPS.

A-1132. *Oreamnos harringtoni* **13,700 ± 500**

Large pellets from 20–25 cm depth.

A-1155. *Oreamnos harringtoni* **10,870 ± 200**

Large pellets from 20–25 cm depth.

A-1167. *Oreamnos harringtoni* **12,980 ± 200**

Large pellets from 25–30 cm depth.

A-1168. *Oreamnos harringtoni* **15,500 ± 600**

Large pellets from 35–40 cm depth.

A-1246. *Oreamnos harringtoni* **17,300 ± 800**

Large pellets from 55–60 cm depth.

Comment: ^{14}C analyses on small pellets date to <11 ka (Robbins, Martin & Long 1984).

20. * **Withers Wallow**

Withers Wallow (NAU QSP site 883; NPS GLCA Accession 82) is a sandstone shelter at 1220 m elevation with a north-northwest aspect. This site contains remnant deposits of laminated fluvial and lacustrine sediments. The south end of the shelter contains a small area of deflating eolian, semicompacted sand with plant debris and dung of *cf. Ovis*, *Bison*, and *Mammuthus*. No described profiles exist nor has there been a formal excavation at this site.

Beta-25419. *Mammuthus* **12,010 ± 160**

Three small fragments of what appeared to be a single, crushed dung bolus were recovered from the loose sand profile. Only one fragment was dated.

Compilations

Table 1 shows 20 localities from the Colorado Plateau that contain dung of megaherbivores, along with other dung types and biotic remains. Seven species of megaherbivores were identified utilizing

TABLE 1. Animal species represented by dung remains from 20 localities on the Colorado Plateau

		Bison sp.	cf. *Camelops*	*Equus* sp.	*Euceratherium collinum*	*Mammuthus columbi*	*Neotoma* spp.	*Nothrotheriops shastensis*	*Oreamnus harringtoni*	cf. *Ovis canadensis*	*Sylvilagus* sp.	Additional biotic remains dated
1	Bare Ladder Shelter	-	-	-	-	-	*	-	*	-	-	*
2	Bechan Cave	-	-	?	*	*	**	**	?	**	**	*
3	BF Alcove	-	**	-	-	-	-	-	-	-	-	*
4	Bida Cave	-	-	-	-	-	**	-	*	**	-	*
5	Chuar Cave	-	-	-	-	-	-	-	*	-	-	-
6	Cottonwood Alcove	-	-	-	*	-	-	-	-	-	-	-
7	Cowboy Cave†	*	-	?	-	*?	**	**	-	-	-	*
8	Disappearing Cave	-	-	-	-	-	-	-	*	-	-	*
9	Grobot Grotto	**	-	-	*	*	**	-	?	**	-	*
10	Hooper's Hollow	*	-	-	**	-	**	-	?	**	-	*
11	Kaetan Cave	-	-	-	-	-	-	-	*	-	-	*
12	Mammoth Alcove	**	-	-	-	*	-	-	-	**	-	*
13	Muav Caves	-	-	-	-	-	-	*	-	-	-	-
14	Oak Haven	**	-	-	**	**	-	-	-	-	-	*
15	Oakleaf Alcove	-	-	*	-	-	-	-	-	-	-	*
16	Rampart Cave	-	-	**	-	-	*	*	*	**	**	*
17	Sandblast Cave	**	**	**	-	-	-	-	*	-	-	*
18	Shrubox Alcove	**	-	-	**	**	-	-	**?	**	-	*
19	Stanton's Cave	**	-	**	-	-	**	-	*	*	-	*
20	Wither's Wallow	**	-	-	-	*	-	-	-	**	-	*
	Number of directly dated occurrences	2	0	1	3	4-5	2	2	8	1	0	17

*Directly ^{14}C dated; **Species present at the site but not directly ^{14}C dated; some remains are only skeletal.
†See text for discussion.

dung: *Bison, Equus, "Euceratherium," Mammuthus, Nothrotheriops, Oreamnos* and *Ovis*, and 79 ^{14}C dates were measured from the sites. Dates on extinct herbivores, from only three sites, BF Alcove, Oak Haven, and Shrubox Alcove, were not directly measured on dung remains. Most sites contain additional associated ^{14}C and U/Th dates on skeletal and botanical remains.

Figure 3 illustrates the number of ^{14}C dates on megafaunal species based on dung analyses. The most detailed temporal record of ^{14}C-dated dung is from the extinct mountain goat, *Oreamnos harringtoni.* A similar record is held for keratinous hornsheaths of the same species (Mead *et al.* 1986b). Additional ^{14}C analyses are more likely to provide a more detailed chronology of the occurrence of the mountain goat, than a particular age. The chronological records of *Mammuthus* and *Nothrotheriops* are not as temporally complete as those of *Oreamnos.* However, the strategy for dating these two species was to provide detail on the "last" occurrence in each deposit.

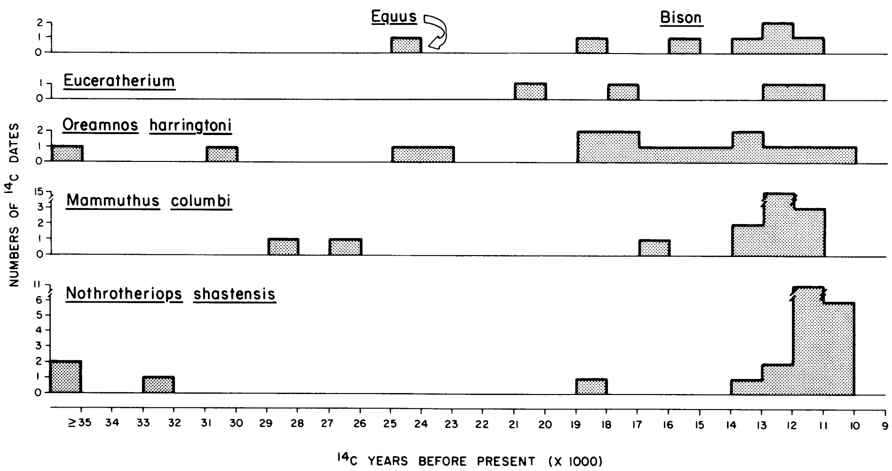

Fig. 3. Numbers of ^{14}C ages directly on Pleistocene dung by millennium. Pleistocene species younger than 10 ka BP have not been ^{14}C analyzed. See text for discussion.

END OF THE PLEISTOCENE

In recent reviews of the chronology of North American late Pleistocene extinctions, Grayson (1989, 1991) indicated that 35 genera of late Pleistocene mammals became extinct at or by the end of the Wisconsin Glacial (see also Martin & Klein 1984; Martin 1987). Grayson used various ^{14}C results in a review of the "quality" of dates (in a compilation of 363 determinations; Mead & Meltzer 1984; Meltzer & Mead 1985). These authors also established a rating system to determine whether or not a particular ^{14}C date was suitable for use as a direct age for a particular species. The two-part rating was from 0 to 9, and those dates rating 8 or 9 were considered suitable or "good" (Grayson 1989, 1991) for use in extinction analyses. Grayson (1989) determined that, of the 35 extinct genera, only 9 taxa contained good dates: *Camelops* (camel), *Equus, Glossotherium* (= *Paramylodon*, ground sloth), *Mammut* (mastodont), *Mammuthus, Megalonyx* (giant ground sloth), *Nothrotheriops, Smilodon* (sabertooth), and *Tapirus* (tapir). Of these 9 taxa, only 7 have good ^{14}C dates for the terminal Wisconsin Glacial (omitting *Glossotherium* and *Megalonyx*).

All ^{14}C analyses on dung presented here rate 9 in the Meltzer and Mead (1985) system. On the Colorado Plateau, deposition of fecal remains of different types, attributed to various extinct or extralocal large mammals, ceased within the same millennium (Fig. 3). ^{14}C dating of hornsheaths and dung of *Oreamnos harringtoni* provides a weighted average time of extinction of 11,160 ± 125 BP (Mead *et al.* 1986b). Weighted average ^{14}C dates of *Mammuthus* dung indicate an extinction time of 11,820 ± 80 BP. Previously, we indicated that a weighted time of extinction for the mammoth was 11,270 ± 65 BP. However, that analysis included the possibly contaminated tusk date (AMS) from Professor Valley, Utah (Agenbroad & Mead 1989). Our present, conservative approach uses the older of the two weighted average dates of dung samples only. Martin, Thompson and Long (1985) indicate a weighted average time of extinction for *Nothrotheriops shastensis* of 11,016 ± 50 BP on dung from a variety of deposits both on and adjacent to the Colorado Plateau.

Bison is last recorded in the deposits by the youngest ^{14}C date of 11,810 ± 140 from Cowboy Cave. However, it is not absolutely certain that *Bison* dung was the actual species analyzed for the age. A *Bison* keratinous hornsheath and hoof were AMS dated from Bison Alcove, Arches National Park, southeastern Utah (Mead, Sharpe & Agenbroad 1991). The dates of 405 ± 65 and 355 ± 60 BP confirm the presence of this species on the Colorado Plateau during the late Holocene, but we do not know whether this species lived on the Plateau throughout the Holocene.

Ovis canadensis is known to have lived throughout the Colorado Plateau during the Holocene. Dung remains of this species from Stanton's Cave were ^{14}C dated (Robbins, Martin & Long 1984). An AMS date on a hornsheath from this cave is 20,540 ± 170 BP (Beta-29498, ETH-4818; Mead & Meltzer, unpublished data), the oldest directly dated remains of this species on the Plateau. Other dates on *Ovis* in this series include 15,000, 12,500 and 1100 BP from both Rampart and Stanton's caves (Mead & Meltzer, unpublished data).

Grayson (1989, 1991) states that it has become increasingly difficult to place a new taxon in the terminal Wisconsin. Although "*Euceratherium*" remains from the Colorado Plateau are not completely understood, dung attributed to this species has been ^{14}C dated no younger than 11,630 ± 150 BP (Bechan Cave).

Although *Bison* sp. and *Ovis canadensis* avoided extinction and local extirpation, and persisted on the Colorado Plateau from the Wisconsin Glacial through the latest Holocene, *Oreamnos harringtoni*, "*Euceratherium collinum*," *Mammuthus columbi* and *Nothrotheriops shastensis* extirpated the region sometime between 11.8 and 11 ka (using weighted averages of youngest ^{14}C dates). We feel that analysis of identified dung and keratinous remains are still considered the most reliable materials to ^{14}C date, when the initial question includes the application of the date to the time of local extirpation. The Colorado Plateau provides a unique preservation habitat, found in greater abundance of deposits and species richness than anywhere else in North America.

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References

Agenbroad, L. D. and Mead, J. I. 1987 Late Pleistocene alluvium and megafauna dung deposits of the central Colorado Plateau. *In* Davis, G. and VandenDolder, E., eds., Geologic diversity of Arizona and its margins: excursions to choice areas. *Arizona Bureau of Geology and Mineral Technology Special Paper* 5: 68–85.

_____1989 Quaternary geochronology and distribution of *Mammuthus* on the Colorado Plateau. *Geology* 17: 861–864.

Agenbroad, L. D., Mead, J. I., Mead, E. M. and Elder, D. 1989 Archaeology, alluvium, and cave stratigraphy: the record from Bechan Cave, Utah. *The Kiva* 4: 335–351.

Cole, K. L. (ms.) 1981 Late Quaternary environments in the eastern Grand Canyon: Vegetational gradients over the last 25,000 years. Unpublished Ph.D. dissertation, The University of Arizona.

_____1982 Late Quaternary zonation of vegetation in the Grand Canyon. *Science* 217: 1142–1145.

_____1990 Late Quaternary vegetation gradients through the Grand Canyon. *In* Betancourt, J. L., Van Devender, T. R. and Martin, P. S., eds., *Packrat Middens: The Last 40,000 Years of Biotic Change*. Tucson, The University of Arizona Press: 240–256.

Cole, K. L. and Mead, J. I. 1981 Late Quaternary animal remains from packrat middens in the eastern Grand Canyon, Arizona. *Journal of the Arizona-Nevada Academy of Science* 16: 24–25.

Davis, O. K., Agenbroad, L. D., Martin, P. S. and Mead, J. I. 1984 The Pleistocene dung blanket of Bechan Cave, Utah. *In* Genoways, H. H. and Dawson, M. R., eds., Contributions in Quaternary Vertebrate Paleontology: A Volume in Memorial to John E. Guilday. *Carnegie Museum of Natural History Special Publication* 8: 267–282.

Davis, O. K., Mead, J. I., Martin, P. S. and Agenbroad, L. D. 1985 Riparian plants were a major component of the diet of mammoths of southern Utah. *Current Research in the Pleistocene* 2: 81–82.

Emslie, S. D. 1987 Age and diet of fossil California condors in Grand Canyon, Arizona. *Science* 237: 768–770.

_____1988 Vertebrate paleontology and taphonomy of caves in Grand Canyon, Arizona. *National Geographic Research* 4: 128–142.

Euler, R. C. 1984 The archaeology, geology, and paleobiology of Stanton's Cave. *Grand Canyon Natural History Association Monograph* 6: 141 p.

Grayson, D. K. 1989 The chronology of North American late Pleistocene extinctions. *Journal of Archaeological Science* 16: 153–165.

_____1991 Late Pleistocene mammalian extinctions in North America: taxonomy, chronology, and explanations. *Journal of World Prehistory* 5: 193–231.

Hansen, R. M. 1978 Shasta ground sloth food habits, Rampart Cave, Arizona. *Paleobiology* 4: 302–319.

_____1980 Late Pleistocene plant fragments in the dungs of herbivores at Cowboy Cave. *In* Jennings, J. D., ed., Cowboy Cave. *University of Utah, Anthropological Papers* 104: 179–189.

Haynes, C. V., Damon, P. E. and Grey, D. C. 1966 Arizona radiocarbon dates VI. *Radiocarbon* 8: 1–21.

Jennings, J. D., ed. 1980 Cowboy Cave. *University of Utah, Anthropological Papers* 104: 224 p.

Laudermilk, J. D. and Munz, P. A. 1938 Plants in the dung of *Nothrotherium* from Rampart and Muav caves, Arizona. *Carnegie Institute of Washington Publication* 487: 271–281.

Long, A., Hansen, R. M. and Martin P. S. 1974 Extinction of the Shasta ground sloth. *Geological Society of America Bulletin* 85: 1843–1848.

Long, A. and Martin, P. S. 1974 Death of American ground sloths. *Science* 186: 638–640.

Lull, R. S. 1930 The ground sloth, *Nothrotherium*. *American Journal of Science* 20: 344–352.

Martin, P. S. 1987 Late Quaternary extinctions: the promise of TAMS ^{14}C dating. *Nuclear Instruments and Methods* B29: 179–186.

Martin, P. S. and Klein, R. G. 1984 *Quaternary Extinctions: A Prehistoric Revolution*. Tucson, The University of Arizona Press. 892 p.

Martin, P. S., Sabels, B. E. and Shutler, D. 1961 Rampart Cave coprolite and ecology of the Shasta ground sloth. *American Journal of Science* 259: 102–127.

Martin, P. S. and Sharrock, F. W. 1964 Pollen analysis of prehistoric human feces: a new approach to ethnobotany. *American Antiquity* 30: 168–180.

Martin, P. S., Thompson, R. S. and Long, A. 1985 Shasta ground sloth extinction: a test of the blitzkrieg model. *In* Mead, J. I. and Meltzer, D. J,. eds., *Environments and Extinctions: Man in Late Glacial North America*. Orono, University of Maine. 5–14.

Mead, J. I. (ms.) 1983 Harrington's extinct mountain goat (*Oreamnos harringtoni*) and its environment in the Grand Canyon, Arizona. Unpublished Ph.D. dissertation, The University of Arizona.

Mead, J. I. and Agenbroad, L. D. 1989 Pleistocene dung and the extinct herbivores of the Colorado Plateau, southwestern USA. *Cranium* 6: 29–44.

Mead, J. I., Agenbroad, L. D., Davis, O. K. and Martin, P. S. 1986a Dung of *Mammuthus* in the arid Southwest, North America. *Quaternary Research* 25: 121–127.

Mead, J. I., Agenbroad, L. D., Martin, P. S. and Davis, O. K. 1984 The mammoth and sloth dung from Bechan Cave in southern Utah. *Current Research in the Pleistocene* 1: 79–80.

Mead, J. I., Agenbroad, L. D., Phillips, A. M. and Middleton, L. T. 1987 Extinct mountain goat (*Oreamnos harringtoni*) in southeastern Utah. *Quaternary Research* 27: 323–331.

Mead, J. I., Martin, P. S., Euler, R. C., Long, A., Jull, A. J. T., Toolin, L. J., Donahue, D.J. and Linick, T.

W. 1986b Extinction of Harrington's mountain goat. *Proceedings of the National Academy of Science* 83: 836–839.

Mead, J. I. and Meltzer, D. J. 1984 North American late Quaternary extinctions and the radiocarbon record. *In* Martin, P. S. and Klein, R. G., eds., *Quaternary Extinctions: A Prehistoric Revolution.* Tucson, The University of Arizona Press: 440–450.

Mead, J. I., Meltzer, D. J., Vogel, J. C. and Lawler, M. C. 1991 Stable carbon and nitrogen isotope ratios of late Pleistocene *Ovis* and *Oreamnos* from the Grand Canyon, Arizona. Abstract. *Journal of the Arizona-Nevada Academy of Science, Supplement*: 28 p.

Mead, J. I., O'Rourke, M. K. and Foppe, T. M. 1986 Dung and diet of the extinct Harrington's mountain goat (*Oreamnos harringtoni*). *Journal of Mammalogy* 67: 284–293.

Mead, J. I., Sharpe, S. E. and Agenbroad, L. D. 1991 Holocene bison from Arches National Park, southeastern Utah. *The Great Basin Naturalist* 51: 336–342.

Meltzer, D. J. and Mead, J. I. 1985 Dating late Pleistocene extinctions: theoretical issues, analytical bias, and substantive results. *In* Mead, J. I. and Meltzer, D. J., eds., *Environments and Extinctions: Man in Late Glacial North America.* Orono, University of Maine: 145–173.

O'Rourke, M. K. and Mead, J. I. 1985 Late Pleistocene and Holocene pollen records from two caves in the Grand Canyon. *In* Fall, P., Jacobs, B. and Davis, O. K., eds., *American Association of Stratigraphic Palynologists* 16: 169–186.

Phillips, A. M. (ms.) 1977 Packrats, plants and the Pleistocene in the lower Grand Canyon. Unpublished Ph.D. dissertation, The University of Arizona.

_____ 1984 Shasta ground sloth extinction. *In* Martin, P. S. and Klein, R. G., eds., *Quaternary Extinctions: A Prehistoric Revolution.* Tucson, The University of Arizona Press: 148–158.

Phillips, A. M. and Van Devender, T. R. 1974 Pleistocene packrat middens from the lower Grand Canyon of Arizona. *Journal of the Arizona Academy of Science* 9: 117–119.

Robbins, E. I., Martin, P. S. and Long, A. 1984 Paleoecology of Stanton's Cave, Grand Canyon, Arizona. *In* Euler, R. C., ed., The archaeology, geology, and paleobiology of Stanton's Cave. *Grand Canyon Natural History Association* 6: 115–130.

Schwartz, D. W., Lange, A. L. and DeSaussure, R. 1958 Split-twig figurines in the Grand Canyon. *American Antiquity* 23: 264–274.

Thompson, R. S., Van Devender, T. R., Martin, P. S., Foppe, T. and Long, A. 1980 Shasta ground sloth (*Nothrotheriops shastense* Hoffstetter) at Shelter Cave, New Mexico: Environment, diet, and extinction. *Quaternary Research* 14: 360–376.

Van Devender, T. R., Phillips, A. M. and Mead, J. I. 1977 Late Pleistocene reptiles and small mammals from the lower Grand Canyon of Arizona. *Southwestern Naturalist* 22: 49–66.

Wilson, R. W. 1942 Preliminary study of the fauna of Rampart Cave, Arizona. *Contributions to Paleontology, Carnegie Institution Publication* 530: 169–185.

Withers, K. (ms.) 1989 Late Quaternary vegetation and climate of Forty-Mile Canyon and Willow Gulch, in the central Colorado Plateau. M.S. thesis, Northern Arizona University.

Withers, K. and Mead, J. I. (ms.) Late Quaternary vegetation and climate in the Escalante River Basin, on the central Colorado Plateau. Submitted to *Great Basin Naturalist.*

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AMS DATING OF A LATE QUATERNARY TEPHRA AT GRAHAM'S TERRACE, NEW ZEALAND

RICHARD GILLESPIE[1], *A. P. HAMMOND*[2], *K. M. GOH*[2], *P. J. TONKIN*[2], *D. C. LOWE*[3]
R. J. SPARKS[3] *and GAVIN WALLACE*[3]

ABSTRACT. The radiocarbon dating of volcanic ash (tephra) deposits in New Zealand has been difficult on sites remote from the eruption, which contain either little carbon or degraded and contaminated charcoal. Although many studies of contamination removal from macroscopic charcoals from tephra sequences have been made, little attention has been paid to those containing no visible charcoal, because of the difficulty of obtaining sufficient carbon for radiometric dating. We report here experiments using accelerator mass spectrometry to establish a reliable method for dating a low-carbon aeolian and peat deposit containing a tephra horizon. Results so far demonstrate that improvements to existing chemical pretreatment methods are possible, and that dates obtained on oxidized fine-grained residues can approach the maximum age determined on good quality charred wood samples.

INTRODUCTION

The Graham's Terrace tephra site is about 9.5 km southeast of Nelson Creek township in the Grey River valley on the South Island of New Zealand (Grid Reference NZMS 260 K32/928588). Mew *et al.* (1986) described the site, and carried out extensive chemical and sedimentological analyses, concluding that the tephra is identical to a widely distributed volcanic ash deposit, variously called Kawakawa, Oruanui, Wairakei or Aokautere. The pooled mean age of four radiocarbon determinations, Q-2665 to -2668, made on carbonized wood fragments, found embedded in non-welded ignimbrite from a major eruption at Taupo in central North Island, New Zealand, is 22,590 ± 230 BP. Other dates on materials associated with the same eruption, at both North and South Island sites, range from 20,550 ± 300 to 21,300 ± 460 BP (Wilson, Switsur & Ward 1988). Acid-washed fine sandy loam from below the tephra layer at the Graham's Terrace site in north western South Island gave an age of 15,600 ± 250 BP (NZ-6557, Mew *et al.* 1986). This discrepancy in ages for the supposedly same event gave initial impetus to the work reported here.

Previous work on macroscopic charcoal from Quaternary deposits in New Zealand have demonstrated that contamination by younger organic carbon is common and difficult to remove completely. Bailey and Lee (1972) and Bailey *et al.* (1975) used extraction with 0.5 mol sodium hydroxide, and concluded that the humic-acid fractions in their samples were not age-affecting contaminants, whereas Goh and Molloy (1972) demonstrated that extraction with alkali/pyrophosphate was an effective pretreatment for charcoals. When using soil organic components for dating, in contrast to buried charcoals, Goh and Pullar (1977) showed that alkali/pyrophosphate extraction was not as effective as hydrolysis with either 6 mol HCl or 72% sulfuric acid, and that solvent extraction also gave an increase in age. Goh, Molloy and Rafter (1977) found that the clay-humus fraction physically sorted from loess deposits was younger than charcoal from the same deposit. Goh (1978) and Hammond *et al.* (1991) concluded that 70% nitric acid hydrolysis was the most effective treatment when soil organic components were used for dating, though in some soils, the amounts of carbon left for dating may be insufficient for conventional radiometric dating. According to Goh (1991), chemical pretreatments used for buried charcoals should be different from those used for soil organic components, because of the different nature of contamination in

[1]Department of Biogeography and Geomorphology, Australian National University, Canberra, ACT 2601 Australia
[2]Department of Soil Science, Lincoln University, Canterbury, New Zealand
[3]Nuclear Sciences Group, Department of Scientific and Industrial Research, Lower Hutt, New Zealand

these materials. With the availability of accelerator mass spectrometry (AMS) technology, and the consequent small-sample capability allowing substantially improved chemical pretreatment, we approached the problem by dating all fractions from many different chemical extractions.

SAMPLE PRETREATMENT

All samples contained 4.5–5.5% organic carbon when analyzed by a chromate oxidation method (Schollenberger 1945). Before chemical pretreatment, samples of *ca.* 200 g were wet-sieved through a 63-μm screen, and 10–20 g subsamples of the fine fraction were used for further work. In all cases, more than 95% by weight passed the 63-μm screen. For the tephra layer itself, some fibrous material was retained on the sieve, and this was processed by standard methods for cellulose preparation (5% $NaClO_2$ in pH3 HCl at 90°C). For the remaining fine-grained samples, two sets of pretreatment methodologies, and the data resulting from these, are described here – one set was carried out by A. P. Hammond and K. M. Goh at Lincoln University, the other set carried out by Richard Gillespie at the Australian National University (ANU).

The Lincoln University techniques follow more-or-less standard practices presently employed in New Zealand and elsewhere, for the radiocarbon dating of soils and sedimentary charcoals (Goh 1991). These methods employ dilute acid and alkali extractions, often called the acid/base/acid sequence, to remove fulvic- and humic-acid contaminants. This involves extraction of humic material with an alkaline solution containing 0.1 mol sodium hydroxide and tetrasodium pyrophosphate, with subsequent precipitation of the humic-acid component using concentrated hydrochloric acid. The fulvic acid remains in solution and may be recovered by evaporation or dialysis. Also used were strong acid treatments, such as 6 mol hydrochloric acid hydrolysis (Scharpenseel 1979), and 70% nitric-acid hydrolysis (Shultz 1962). A graded-strength organic solvent extraction sequence, using acetone, petroleum spirit, ethanol/benzene and methanol/chloroform under reflux conditions (Hance & Anderson 1963), and the simpler technique of ultrasonic agitation in chloroform (Fowler, Gillespie & Hedges 1986), were used for lipid extractions. We also used a pollen analysis preparation (N. Moar, personal communication 1988) with the sequence:

1. Boiling 10% KOH solution
2. Wet sieving
3. Boiling 10% HCl
4. Digestion in hot 40% HF
5. Hypochlorite bleach
6. Acetolysis with hot concentrate H_2SO_4/acetic anhydride.

At ANU, we explored techniques borrowed from those used to prepare samples for pollen analysis and fire history in Australia (Gray 1965; Clark 1983; Singh & Geissler 1985). These chemical procedures are designed to remove most inorganic and organic materials except pollen and fine charcoal from fine-grained sediments. After some preliminary trials with samples from other sites (Gillespie *et al.* 1991), we developed the following pretreatment sequence:

1. Wet seive to pass 63 μm, acidify with HCl to ~pH1, centrifuge and wash
2. Extraction with alkali (either hot 10% KOH or cold 0.1 mol $NaOH/Na_4P_2O_7$)
3. Digestion with hot 40% HF
4. Oxidation with 10% $KClO_3$ in 35% HNO_3 (dilute Shultze solution (Gray 1965))
5. Extraction with cold 5% ammonia solution
6. Reacidification with HCl.

All operations after the initial sieving are carried out in the same 50-ml polypropylene centrifuge tube to minimize contamination introduced in the laboratory (Gillespie & Hedges 1984), and to allow the use of the hot hydrofluoric acid solution. The alkali solutions remove dark humic materials; several extractions are usually needed, and long centrifuge times are sometimes necessary to spin down all of the fine sediment. One improvement to this scheme might be to perform the hydrofluoric acid digestion before the alkali extraction, since destruction of clay minerals and clay-organic complexes makes the alkali treatment more effective, and centrifugation is faster with the clays removed. Silicates are destroyed in the HF digestion stage, the most significant loss occurring during the first hour of heating in a boiling water bath. Caution is necessary for this step, because some samples react very violently – slow addition of HF, gentle stirring and a resting period to allow any initial reaction to subside should precede heating. For sediments containing calcium or aluminum, it is advantageous to add 10% hydrochloric acid to the hydrofluoric acid solution to avoid precipitation of insoluble fluorides. Oxidation with dilute Schultze solution may also be quite vigorous, requiring similar caution, and no heating is normally required. This oxidation reagent is stronger than the hypochlorite bleach used for the New Zealand sequence above, but does not oxidize pollen. The Schultze oxidation releases more dark humic material; this can be extracted with any alkaline solution, the 5% ammonia solution used here is effective, simple to prepare and volatile.

Pretreated samples were combusted in evacuated and sealed quartz tubes with copper II oxide and silver wire. The purified CO_2 was then converted to graphite, following a method developed by Lowe and Judd (1987). Sample CO_2 is introduced with hydrogen into a quartz reaction vessel containing finely divided iron powder. At 700°C, the CO_2 is reduced to graphite, which is deposited on the iron catalyst. This mixture is pressed into a copper target holder for insertion into the AMS system. All graphite targets were measured in the Nuclear Sciences Group (INS) AMS facility in the same way (Wallace *et al.* 1987). The sample ^{14}C count rates, normalized to the ^{13}C currents, were compared with the normalized count rate from a target prepared from the NBS oxalic acid modern standard. Measurement of each sample target was broken into three runs of 10 min each, with the standard counted at the beginning, middle and end of each sequence. Any drift in the system could be detected and compensated for, during this procedure. Experimental errors assigned to the results are based on counting statistics, with an extra term to account for any non-statistical scatter indicated by applying a chi-square test to the measured values.

In calculating the ^{14}C ages of the samples, the ^{14}C count rates were corrected for the different natural carbon isotopic abundances in samples and standard (using $\delta^{13}C$ values from separate measurements on the same CO_2 used to prepare the graphite target), and then normalized to $\delta^{13}C = -25‰$ for samples, and $\delta^{13}C = -19‰$ for the modern standard. Dates reported are conventional ^{14}C ages, as defined by Stuiver and Polach (1977), based on the Libby half-life of 5568 years.

Results and Discussion

Taking the series of chemically separated fractions, processed at Lincoln University, from Profiles 5 and 7 (Table 1), all acid-soluble preparations yield ages younger than that of an untreated sample (12.57 ± 0.37 ka BP, NZA-262). The fraction insoluble in 6 mol HCl is the same age as the untreated sample, indicating that there is little protein or other easily hydrolyzed organic component in the sediment. The fraction soluble in organic solvents (NZA-239) is older than the untreated sample, but still considerably younger than 22.6 ka, the presumed age of the tephra deposition. In this series, the oldest dates are obtained on the residue after hydrolysis/oxidation with 70% nitric acid, which has previously been an effective pretreatment for soil organic matter in peats (Goh 1978). Hammond *et al.* (1991) have discussed the significance of the other dates in this series.

TABLE 1. AMS Dates From Graham's Terrace, Profiles 5 and 7*

Lab no.	Location	Fraction dated	$\delta^{13}C$	Age BP
NZA-264	P5, 0–5 cm below tephra	0.1 mol HCl/0.3 mol HF soluble		5975 ± 250
NZA-258	P5, 0–5 cm below tephra	Fulvic acid, extracted with 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$		7770 ± 265
NZA-256	P5, 0–5 cm below tephra	6 mol HCl soluble	−27.1	8710 ± 300
NZA-287	P5, 0–5 cm below tephra	70% HNO_3 soluble	−26.5	12,080 ± 345
NZA-271	P5, 0–5 cm below tephra	Residue after 6 mol HCl	−28.5	12,525 ± 170
NZA-262	P5, 0–5 cm below tephra	Untreated		12,565 ± 365
NZA-327	P7, 0–5 cm above tephra	Residue after hot 1 mol HCl, 0.1 mol NaOH/0.1 mol $Na_{42}O_7$	−28.6	14,410 ± 215
NZA-239	P5, 0–5 cm below tephra	Lipids, extracted with the solvent sequence: acetone, petroleum spirit ethanol/benzene, methanol/chloroform		15,205 ± 240
NZA-335	P5, 0–5 cm below tephra	NZ pollen preparation (see text)	−28.3	15,240 ± 510
NZA-325	P7, 0–5 cm below tephra	Residue after hot 1 mol HCl, 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$	−28.5	15,490 ± 250
NZA-371	P5, 0–5 cm above tephra	Residue after 70% HNO_3	−26.7	15,540 ± 240
NZA-909	P5, 0–5 cm above tephra	Repeat of NZA-371 after second treatment with 70% HNO_3	−29.7	16,740 ± 230
NZA-270	P5, 0–5 cm below tephra	Residue after 0.1 mol HCL/0.3 mol HF, 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$	−28.7	17,515 ± 460
NZA-263	P5, 0–5 cm below tephra	Residue after 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$		17,900 ± 335
NZA-293	P5, 0–5 cm below tephra	Residue after 70% HNO_3	−30.2	18,810 ± 380
NZA-373	P7, 0–5 cm below tephra	Residue after 70% HNO_3	−28.8	19,170 ± 480
NZA-372	P5, 50 cm below tephra	Residue after 70% HNO_3	−26.7	20,670 ± 470

*Samples pretreated at Lincoln University, New Zealand, by Hammond and Goh.

For the samples processed at ANU from 5 cm above and below the tephra layer in Profile 4B (Table 2), we observe the same younger ages for acid- or alkali-soluble fractions, but the oldest fraction (NZA-323: 21 ka) is now the residue after the full sequence of alkali extraction, hydrofluoric-acid digestion, chlorate oxidation and a second alkali extraction. Investigations on other sites (Gillespie 1990; Gillespie *et al.* 1992) have shown that the second alkali extraction removes humic-type material solubilized by the oxidation treatment, and which is similar in age to the standard humic-acid fraction. Residues were examined microscopically and at 400× magnification. It is clear that hot 70% nitric acid destroys pollen and other non-charred botanical debris, whereas the 35% nitric acid/10% potassium chlorate solution, when used at room temperature, leaves most pollen intact. Neither oxidant destroys the fine-grained black material, although a significant amount of carbon is lost with both reagents. Samples over- or underlying the tephra, from Profiles 4B, 5 and 7, were treated with hot 70% nitric acid, followed by cold 6 mol nitric acid. Material soluble in this reagent gave 12,080 ± 345 BP (NZA-287), an age almost identical to the untreated material. The insoluble fractions range in age from 15,540 ± 240 to 19,635 ± 330 BP (NZA-293, -329, -371, and -373). Goh (1991) has shown that this reagent gives maximum ages for buried soils and sediments, whereas the ages at this site are inconsistent. However, the maximum date overlaps with that from the full sequence (with chlorate oxidation) on the same material. The alkali extraction of humic acid is not carried out in the 70% nitric-acid treatment, which probably accounts for the younger, more variable ages on fractions insoluble in this reagent. For those with appropriate laboratory facilities, the full sequence of extractions has several attractions. The 70% nitric-acid treatment is simpler to perform and useful for fieldworkers.

We have a conceptual problem with this "black stuff" – we have not positively identified it as charcoal at Graham's Terrace, although it is convenient to think of it in this way. In some sedi-

TABLE 2. AMS Dates From Graham's Terrace Profile 4B*

Lab no.	Location	Fraction dated	$\delta^{13}C$	Age BP
NZA-248	Tephra layer	Cellulose, after $NaClO_2$/HCl bleach of fibrous material seived out	−27.2	10,485 ± 810
NZA-238	0–5 cm above tephra	Humic acid, extracted with 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$		11,265 ± 175
NZA-328	0–5 cm above tephra	Untreated	−28.2	11,870 ± 120
NZA-232	Tephra layer	Humic acid, extracted with 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$		12,170 ± 160
NZA-234	Tephra layer	Residue after hot 1 mol HCl, 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$	−28.3	12,685 ± 210
NZA-241	Tephra layer	Residue after 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$, 40% HF, 35% HNO_3/10% $KClO_3$,NH_3	−29.5	15,780 ± 370
NZA-236	0–5 cm below tephra	Humic acid, extracted with 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$		16,025 ± 210
NZA-329	0–5 cm above tephra	Residue after 70% HNO_3	−30.3	19,635 ± 330
NZA-247	0–5 cm above tephra	Residue after 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$, 40% HF, 35% HNO_3/10% $KClO_3$,NH_3	−28.5	20,240 ± 450
NZA-323	0–5 cm below tephra	Residue after 0.1 mol NaOH/0.1 mol $Na_4P_2O_7$, 40% HF, 35% HNO_3/10% $KClO_3$,NH_3	−28.9	21,010 ± 395

*Samples pretreated at the Australian National University by Gillespie

ments, it is charcoal and has a similar size range to pollen (Clark 1983). For other sediments, such as the ones we used here, the black particles are smaller (generally <10 μm), and require further study to determine their origin and structure. However, both the pollen and the black particles probably arrive in the sediments by similar processes (notably wind or water deposition) at similar times, and the black particles are certainly very resistant to chemical attack.

We have not been able to obtain maximum dates for the tephra layer, itself, because it does not appear to contain the same quantity of residual fine charcoal as the peaty soils over- and underlying it. The tephra layer does, however, contain some probable root material and the same amount of soluble humic material as the peaty soils above and below it. Both of these fractions gave a falsely young age for the deposit.

Questions remain about the different approaches to dating tephra and other deposits with little carbon. Campbell (1986) obtained dates of 21,300 ± 450 (NZA-7144) and 21,300 ± 460 (NZA-7373) for peat over- and underlying the Kawakawa Tephra at Howard's River, near Nelson, using gas proportional radiometric ^{14}C with minimal pretreatment (acid wash only), whereas AMS dates obtained by one of us (A.P.H.), using the 70% nitric-acid pretreatment on samples from the same sampling intervals as Campbell, gave 18,920 ± 420 (NZA-907) and 19,660 ± 280 (NZA-908). These two sets of data are significantly different, and the samples given a supposedly good pretreatment are younger than untreated samples. Several possible reasons for this difference remain unexplored:

1. Calibration and background subtraction procedural differences between the radiometric and AMS laboratories, which could invalidate the comparisons
2. Unaccounted laboratory contamination introduced during the pretreatment of AMS samples, which may add modern carbon to the measured sample
3. Incomplete combustion of low-carbon samples, which could result in a bias toward the younger, more volatile components not removed during pretreatment, and perhaps most likely,

4. Difficulties of association of samples with the event to be dated when the site is remote from that event (subsequent AMS dating of the same samples dated radiometrically by Campbell gave 20,490 ± 340 and 21,040 ± 335 BP) (Table 3).

TABLE 3. Other Dates From Kawakawa Tephra Sites*

Lab no.	Location	Fraction dated	$\delta^{13}C$	Age BP
Q-2665 to Q-2668	Within ignimbrite at four sites near source of eruption	Acid- and alkali-washed charred wood (pooled mean of four determinations)	−23.2	22,590 ± 230
NZ-7373	Above tephra	Peat, acid-washed	−28.1	21,300 ± 460
NZA-2066		AMS date on same sample		21,040 ± 335
NZ-7144	Below tephra	Peat, acid-washed	−27.4	21,300 ± 450
NZA-2067		AMS date on same sample		20,490 ± 340
NZA-908	Below tephra	Peaty soil after 70% HNO_3	−29.8	18,920 ± 420
NZA-907	Above tephra	Peaty soil after 70% HNO_3	−29.6	19,660 ± 280
NZ-6557	Below tephra	Acid washed fine sandy loam	–	15,600 ± 250

*Q-dates on charred wood from North Island sites, NZ dates on peat from Howard's River, South Island, discussed by Wilson, Switsur and Ward (1988); NZA dates from same Howard's River site, pretreated by Hammond

CONCLUSIONS

The commonly used acid/base/acid extraction techniques for removing contaminants before ^{14}C dating of soils do not yield acceptable dates for the sediments in the Graham's Terrace sequence. Maximum ages are only obtained by treatment with hot 70% nitric acid, or with a more complicated sequence involving chlorate oxidation. Although the samples contain 4–5% organic carbon, most of this is present as younger contaminants, particularly humic materials, which, in these fine-grained sediments, are resistant to the standard pretreatment methods. Some mineral destruction seems to be necessary to remove organic material associated with the fine silt/clay fraction, before oxidation can have the desired effect of rendering soluble the alkali-resistant humic carbon. Given these findings, it was possible to achieve dates within a few percent of the known age defined by measurements on well-preserved, uncontaminated charred wood. Because there are good reasons why we would expect dates on soil or peat organic components to be younger than equivalent charcoal, we view this as a significant success. The concept of dating silt-sized charcoal and pollen has the potential to provide reasonable ages for fine-grained sediments containing very little carbon, and is being further explored at other sites in alluvial, lacustrine and aeolian environments (Gillespie 1990; Gillespie *et al.* 1991, 1992).

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REFERENCES

Bailey, J. M. and Lee, R. 1972 The effect of alkaline pretreatment on the radiocarbon dates of several New Zealand charcoals. *In* Grant-Taylor, T. L. and Rafter, T. A., eds., *Proceedings of the 8th International ^{14}C Conference*. Wellington, The Royal Society of New Zealand: G46–55.

Bailey, J. M., Lee, R., Rankin, P. C. and Spier, T. W. 1975 Humic acid contamination of charcoals from Quaternary tephra deposits in New Zealand. *In* Suggate, R. P. and Cresswell, M. M., eds., *Quaternary Studies*. Wellington, The Royal Society of New Zealand: 53–55.

Campbell, I. B. 1986 New occurrences and distribution of Kawakawa Tephra in South Island, New Zealand. *New Zealand Journal of Geology and Geophysics* 29: 425–435.

Clark, R. J. 1983 Pollen and charcoal evidence for the effects of aboriginal burning on the vegetation of Australia. *Archaeology and Physical Anthropology in Oceania* 18: 32–37.

Fowler, A. J., Gillespie, R. and Hedges, R. E. M. 1986 Radiocarbon dating of sediments by accelerator mass spectrometry. *Physics of the Earth and Planetary Interiors* 44: 15–20.

Gillespie, R. 1990 On the use of oxidation in AMS sample pretreatment. *In* Yiou, F. and Raisbeck, G. M., eds., Proceedings of the 5th International Conference on Accelerator Mass Spectrometry. *Nuclear Instruments and Methods* B52: 345–347.

Gillespie, R. Dlugokencky, E., Sparks, R. J., Wallace, G., Prosser, I. P. and Chappell, J. M. A. 1992 AMS dating of alluvial sediments on the Southern Tablelands of New South Wales. *Radiocarbon*, this issue.

Gillespie, R. and Hedges, R. E. M. 1984 Laboratory contamination in radiocarbon accelerator mass spectrometry. *Nuclear Instruments and Methods* 233: 294–296.

Gillespie, R., Magee, J. W., Luly, J. G., Dlugokencky, E., Sparks, R. J. and Wallace, G. 1991 AMS radiocarbon dating in the study of arid environments: Examples from Lake Eyre, South Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 84: 333–338.

Goh, K. M. 1978 Removal of contaminants to improve the reliability of radiocarbon dates of peat. *Journal of Soil Science* 29(3): 340–349.

____1991 Carbon dating. *In* Coleman, D. C. and Fry, B., eds., *Carbon Isotope Techniques*. San Diego, Academic Press, Inc.: 125–145.

Goh, K. M. and Molloy, B. J. P. 1972 Reliability of radiocarbon dates from buried charcoals. *In* Grant-Taylor, T. L. and Rafter, T. A. eds., *Proceedings of the 8th International Radiocarbon Conference*. Wellington, The Royal Society of New Zealand: G29–45.

Goh, K. M., Molloy, B. J. P. and Rafter, T. A. 1977 Radiocarbon dating of Quaternary loess deposits, Banks Peninsular, Canterbury, New Zealand. *Quaternary Research* 7: 177–196.

Goh, K. M. and Pullar, W. A. 1977 Radiocarbon dating techniques for tephras in central North Island, New Zealand. *Geoderma* 18: 265–278.

Gray, J. 1965 Extraction techniques. *In* Kummel, B. and Raup, G., eds., *Handbook of Palaeontological Techniques*. San Francisco, W. H. Freeman & Co.: 530–587.

Hammond, A. P., Goh, K. M., Tonkin, P. J. and Manning, M. R. 1991 Chemical pretreatments for improving the radiocarbon dates of peats and organic silts in a gley podzol environment, Graham's Terrace, North Westland. *New Zealand Journal of Geology and Geophysics* 34: 191–194.

Hance, R. L. and Anderson, G. 1963 Extraction and estimation of soil phospholipids. *Soil Science* 96: 94–98.

Lowe, D. C. and Judd, W. J. 1987 Graphite target preparation for radiocarbon dating by accelerator mass spectrometry. *Nuclear Instruments and Methods* B28: 113–116.

Mew, G., Hunt, J. L., Froggart, P. C., Eden, D. N. and Jackson, R. J. 1986 An occurrence of Kawakawa Tephra from the Grey Valley, South Island, New Zealand. *New Zealand Journal of Geology & Geophysics* 29: 315–322.

Scharpenseel, H. W. 1979 Soil fraction dating. *In* Berger, R. and Suess, H. E., eds, *Radiocarbon Dating*. Proceedings of the 9th International ^{14}C Conference. Berkeley, University of California Press: 279–284.

Schollenberger, C. J. 1945 Determination of soil organic matter. *Soil Science* 59: 53–56.

Shultz, H. (ms.) 1962 Studies in Radiocarbon Dating. Thesis, Pennsylvania State University, State College, Pennsylvania: 57.

Singh, G., and Geissler, E. A. 1985 Late Cainozoic history of vegetation, fire, lake levels and climate at Lake George, New South Wales, Australia. *Philosophical Transactions of the Royal Society of London* B311: 379–447.

Stuiver, M. and Polach, H. A. 1977 Discussion: Reporting of ^{14}C data. *Radiocarbon* 19(3): 355–363.

Wallace, G., Sparks, R. J., Lowe, D. C. and Pohl, K. P. 1987 The New Zealand accelerator mass spectrometry facility. *Nuclear Instruments and Methods* B28: 124–128.

Wilson, C. J. N., Switsur, V. R. and Ward, A. P. 1988 A new ^{14}C age for the Oruanui (Wairakei) eruption, New Zealand. *Geological Magazine* 125: 297–300.

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AMS DATING OF ALLUVIAL SEDIMENTS ON THE SOUTHERN TABLELANDS OF NEW SOUTH WALES, AUSTRALIA

RICHARD GILLESPIE[1], I. P. PROSSER[2], EDWARD DLUGOKENCKY[3], R. J. SPARKS[3] GAVIN WALLACE[3], and J. M. A. CHAPPELL[1]

ABSTRACT. The dating of alluvial deposits is frequently hampered by a lack of good-quality charcoal or other material for radiocarbon samples. We have dated two sites in southeastern Australia using traditional radiometric methods with minimal pretreatment. Results yielded an inconsistent chronology, affected by contamination with younger humic materials. A more consistent and older chronology was achieved using AMS dating of rigorously pretreated samples of fine-grained charcoal. The results have important implications for the radiocarbon dating of many Late Quaternary stratigraphic sequences with low charcoal abundance.

INTRODUCTION

Alluvial deposits of small drainage basins provide records of the history of erosion that have long been used to determine the controls on denudation and landform evolution. Of particular interest is whether cycles of valley aggradation and degradation are controlled by regional changes in climate or land use, or whether they are controlled by local factors, such as extreme floods or intrinsic instability within each basin (Patton & Schumm 1981; Schick 1974). The radiocarbon chronology of deposition has been central to the discussion. Those invoking climatic changes as the control on denudation refer to synchronous changes in aggradation across many catchments as independent evidence for climatic change (Knox 1983; Williams 1978). In contrast, a lack of regionally synchronous deposition has been used to dismiss environmental change as the control on denudation, and to invoke localized catastrophic events or intrinsic geomorphic changes (Young & Nanson 1982; Prosser 1991). Both arguments rely upon accurate dating of the alluvial sediments, which may not always have been achieved in the past because of incomplete removal of contaminants in the samples or insufficient material for dating.

We report here the problems encountered in dating detrital charcoal and bulk organic sediment from two headwater drainage basins of the Murrumbidgee River, using conventional sample preparation and radiometric dating techniques. In particular, contamination by younger organics in the sediments resulted in an incomplete, and, at times, internally inconsistent chronology of deposition.

The small sample size required by accelerator mass spectrometric (AMS) radiocarbon dating makes more rigorous and destructive sample preparation techniques feasible, and was used here to resolve the conflicting results from earlier radiometric dating. We describe a technique for the removal of contaminants, based upon pollen preparation techniques, together with the implications for the original chronologies.

SITE DETAILS AND STRATIGRAPHY

Wangrah Creek and the Lanyon alluvial fan are located on the Southern Tablelands of New South Wales, 80 and 20 km south of Canberra, respectively (Fig. 1). At Wangrah Creek, a 10-km-long continuous gully has incised to bedrock through a narrow alluvial flat, revealing a sequence of late

[1]Department of Biogeography and Geomorphology, Australian National University, Canberra, ACT 2601 Australia
[2]School of Geography, University of New South Wales, Kensington, Australia
[3]Institute of Nuclear Sciences, DSIR, Lower Hutt, New Zealand

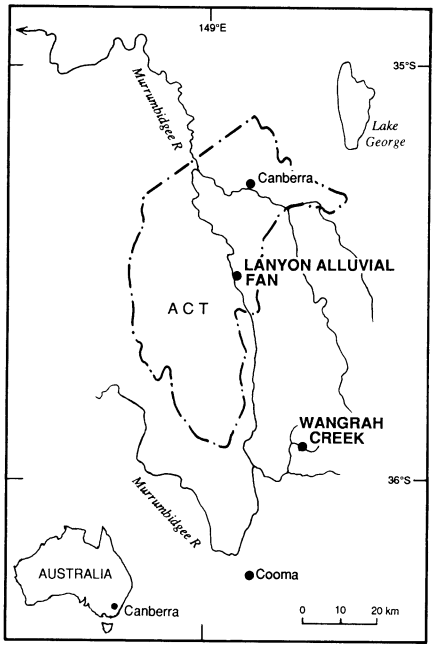

Fig. 1. Location of Lanyon Fan and Wangrah Creek alluvial sites in southeastern Australia

Quaternary alluvial deposits. Prosser (1988) determined the stratigraphy and ^{14}C chronology of the deposits from exposures in the gully walls and cores from the adjacent terrace. A similar situation occurs at Lanyon, where a gully has eroded up the southern side of a 1-km-long, low-angle, alluvial fan adjacent to the Murrumbidgee River, revealing a sequence of fan and valley fill units mapped by Mullins (1985).

Gully walls at Wangrah Creek reveal three major alluvial units, Swampy Meadow Units (SMU) 1 to 3, in order of increasing age. Each unit represents a major phase of aggradation preceded by a phase of gully erosion that removed much of the previously deposited sediment (Prosser 1991). The buried walls of previous gullies can be observed in some sections, but each unit aggraded to a slightly higher level than the previous one, so that, in most sections, the units are arranged as overlying sheets separated by subhorizontal disconformities (Fig. 2). The units consist of uniform, highly bioturbated and mildly organic, fine sandy muds. The sediment is identical to that accumulating in ungullied valleys of the region, where flows thread through a saturated surface densely covered in tussock grasses and sedges; hence, the term, Swampy Meadow Units. Sheets of sand were deposited over SMU 1 at the foot of discontinuous gullies in the initial stages of the present gully erosion.

Mullins (1985) identified six alluvial units at the Lanyon fan, named in order of increasing age. Unit 1 contains benches of sand and gravel confined within the present gully, and Unit 2 consists of discontinuous sand sheets similar to those overlying SMU 1 at Wangrah Creek. Underlying Unit 2 are four major alluvial units, up to 2.0 m thick, which are continuous along the length of gully and separated by subhorizontal disconformities (Fig. 3). Unit 3 is characteristic of fan sediments, containing many planar beds and shallow channels of imbricated gravels and sands, separated by thicker deposits of sandy muds. Units 4, 5 and 6 fine upwards from massive clayey sands and coarse sandy clays at the base to bioturbated, black organic clays at the top, similar to the Swampy Meadow Units of Wangrah Creek. All of the six units on the fan were deposited by fluvial processes.

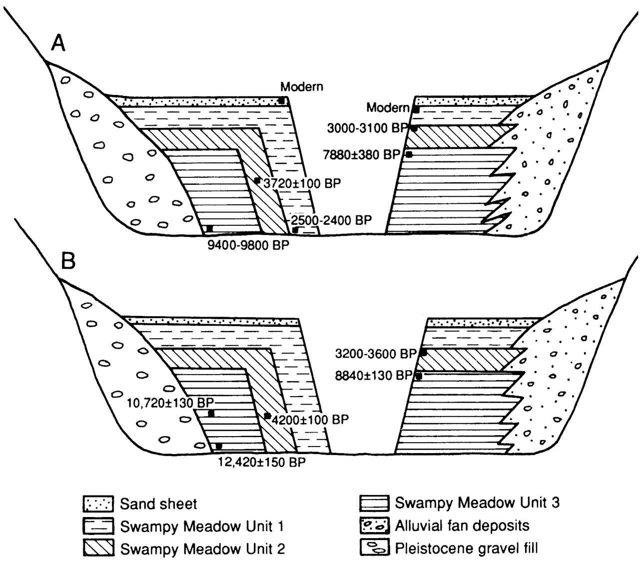

Fig. 2. Wangrah Creek stratigraphy. A. Radiometric chronology; B. AMS chronology.

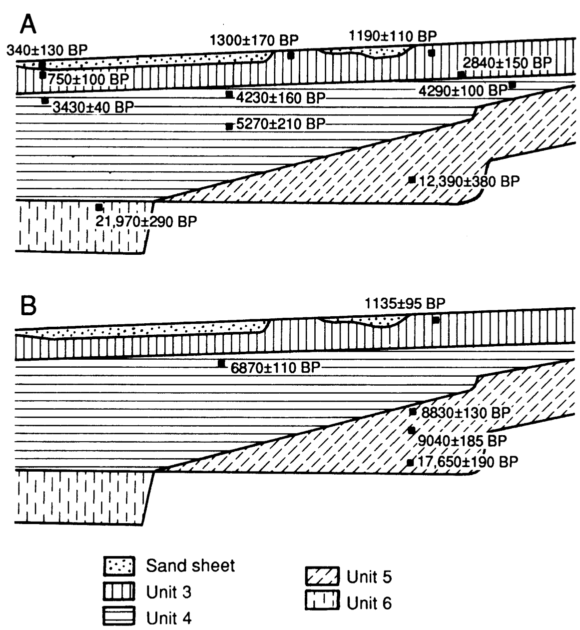

Fig. 3. Lanyon Fan stratigraphy. A. Radiometric chronology; B. AMS chronology.

Vertical movement of material in the older units is evident at both sites, which may have introduced contaminants to the sampled charcoal fragments. Complexes of iron, manganese and organics have precipitated around biotubules in the lower parts of the units and charcoal is absorbing oxides to give a similar appearance. Prosser (1988) and Mullins (1985) noted a general decrease in organic content with increasing age at both sites, which, given the close similarities in the lithology of the units, may reflect gradual loss of organics by leaching, complexing and oxidation. Organic carbon content ranges from 0.2 to 4% at Wangrah Creek and from 0.4 to 1.2% at Lanyon.

Sampling and Pretreatment Chemistry

We collected most samples for radiometric dating at Wangrah Creek from lenses of detrital charcoal, containing fragments *ca.* 1 cm in diameter. Other, less satisfactory samples were from smaller, soft charcoal fragments disseminated throughout the sediment. All samples were given minimal pretreatment, which is standard practice for routine radiometric dating, often simply an acid wash. A few samples were also given an alkali extraction (M. J. Head, personal communication). We used both detrital charcoal and bulk samples of organic sediment for radiometric dating at Lanyon. Bulk samples were washed in alkali solution to extract humic acids, and the insoluble residues were then dated. The bulk samples give a minimum age for the sediment, because they probably include organics derived from plant growth after deposition ceased.

AMS samples were collected as bulk sediment lumps from cleaned back exposures in the present creek beds, slurried in water and equilibrated with 1 mol HCl, then washed through standard sieves. For most samples, only the fine fraction passing a 63 μm (230 mesh) sieve was used for the subsequent experiments. The fine fraction was dried at room temperature under reduced pressure, since we have observed that high-temperature drying (>50°C) may lead to the mobile organic components becoming very resistant to dissolution. A sequence of chemical extractions, developed from the preparation of samples for pollen and charcoal particle counting (Gray 1965; Singh 1981; Clark 1983), were used to remove soluble organic materials and most of the mineral components:

1. Cold extraction with 10% KOH, repeated until no further color was present in the solution
2. Hot 40% HF digestion for 2–3 h, repeated until most of the inorganic material dissolved
3. Cold oxidation with 10% $NaClO_3$ in 35% HNO_3 for 30–60 min
4. Cold extraction with 5% NH_3 solution
5. Reacidification with cold 1 mol HCl.

Each step was followed by washing with distilled water, and centrifuging at 3000 rpm to separate solutions from the residue. The rationale for this sequence is that the alkali solutions remove humic and fulvic acids, the HF destroys clay/organic complexes, and the oxidation renders any remaining organic material soluble in alkali. This sequence of chemical extractions results in the production of residual samples containing mainly pollen and fine charcoal particles. Dates on this material have yielded maximum ages for other fine-grained sedimentary materials (Gillespie *et al.* 1991, 1992).

Discussion of Radiometric Dating Results

Wangrah Creek

Table 1 lists radiometric dates from Wangrah Creek, which show increasing inconsistency in the ^{14}C results with increasing age of units. The top of SMU 1, the sand sheets and charcoal from deposits in the present gully all have a modern age (ANU-5512, -4452, -5513), consistent with historical records that show that SMU 1 was still being deposited in 1842 (Prosser 1991). There are four consistent samples that show the base of the unit started accumulating between 2.5 and 3 ka BP (ANU-5394, -5364, -5451, -5365), and several consistent ages from various depths within the unit (ANU-5393, -4453, -5454, -4454, -4455, -5367).

Dates from the upper part of SMU 2 are similar to, or overlapping with, the well-controlled age of SMU 1 (ANU-5453, -5317, -5714, -5368). Two poor samples (ANU-5366, -5583) from transect WCT 8 are chronologically inverted (neither offer a feasible age), and the base of the unit is undated, but must be >3.7 ka BP (ANU-5035). The base of SMU 3 was consistently dated at 9.5–10 ka BP from three good lenses of charcoal (ANU-5395, -5510, -5369). Samples from an upstream site, however, gave the same age for the top and bottom of the unit, despite separation by 1 m of massive sandy mud (ANU-5715, -4457), and another sample from the middle of the unit gave an inconsistent result (ANU-5351). In earlier papers on Wangrah Creek, Prosser (1987, 1990) reported a fourth alluvial unit, older than SMU 3. Reconsideration of the stratigraphic relationships in the field, in the light of the new AMS dates, showed no clear evidence for a fourth alluvial unit, which is now considered to be a part of SMU 3.

TABLE 1. Radiometric Dates From Wangrah Creek

ANU-no.	Location	Sample material	Age (yr BP)
4452	Sandsheet	Coarse charcoal	Modern
5513	Channel	Coarse charcoal	Modern
5512	Top Unit 1	Coarse charcoal	Modern
5393	50 cm from top Unit 1	Coarse charcoal	810 ± 110
4453	40 cm from top Unit 1	Coarse charcoal	870 ± 120
5454	100 cm from top Unit 1	Coarse charcoal	1150 ± 130
4454	Middle Unit 1	Coarse charcoal	1380 ± 90
4455	Middle Unit 1	Coarse charcoal	1370 ± 80
4799	Middle Unit 1	Coarse charcoal	1760 ± 160
5367	Middle Unit 1	Coarse charcoal	2190 ± 100
5394	55 cm above base Unit 1	Coarse charcoal	2480 ± 160
5364	50 cm above base Unit 1	Coarse charcoal	2720 ± 120
5451	Base Unit 1	Coarse charcoal	2910 ± 130
5365	40 cm above base Unit 1	Coarse charcoal	2950 ± 100
5714	Top Unit 2	Coarse charcoal	2140 ± 290
5453	Top Unit 2	Coarse charcoal	3000 ± 150
5317	Top Unit 2	Coarse charcoal	3110 ± 130
5368	Middle Unit 2	Coarse charcoal	3290 ± 120
5035	Middle Unit 2	Coarse charcoal	3720 ± 100
5583	Middle Unit 2	Fine charcoal	9570 ± 170
5366	Base Unit 2	Fine charcoal	2870 ± 160
5351	Middle Unit 3	Fine charcoal	6710 ± 410
5715	Top Unit 3	Coarse charcoal	7880 ± 380
4457	Base Unit 3	Coarse charcoal	7840 ± 100
5395	Base Unit 3	Coarse charcoal	9410 ± 220
5369	Base Unit 3	Coarse charcoal	9840 ± 380

Lanyon Fan

Table 2 lists radiometric dates from Lanyon. Unit 6 was deposited some time before 22 ka BP (ANU-4707) and the upper, organic part of Unit 5 was deposited before 12.4 ka BP (ANU-4709). The minimum age of the top of Unit 4 is 4.2–4.3 ka BP from both a burned root and a bulk sample (ANU-4665, -4711). A third sample further downstream gave a younger age of 3430 ± 40 BP (ANU-4706). Charcoal at the base of Unit 3 was dated at 2840 ± 100 BP (ANU-4710), consistent with two other charcoal samples from further up the unit (ANU-4712, -4668). A bulk sample from the top of the unit showed that deposition had ceased by 750 ± 100 BP (ANU-4705). Charcoal at the apex of the fan and in Unit 2 was dated as modern and 340 ± 130 BP, respectively (ANU-4666, -4667, -4704).

At both sites, determination of a complete ^{14}C chronology was hampered by inconsistent results and a paucity of coarse detrital charcoal. At least five samples from Units 2 and 3 at Wangrah

Creek gave anomalously young ages (ANU-5714, -5366, -5368, -5351 and -4457), suggesting contamination from organics leached from above. The bulk samples at Lanyon also probably underestimate the age of the sediment. One sample from Wangrah Creek was anomalously old (ANU-5583), possibly a result of reworking of older charcoal into the deposits, a process that Blong and Gillespie (1978) identified for fluvial charcoal. However, reworking is not considered to be a problem at either site, provided coarse charcoal is sampled, because the fragments are extremely fragile. The chronology of both sites supports this interpretation, with the ages of the youngest deposits converging on the known historical age for the gully erosion that terminated deposition.

TABLE 2. Radiometric Dates From Lanyon

ANU-no.	Location	Sample material	Age (yr BP)
4666	Fan apex	Charcoal (tree root)	152.3 ± 2.3 pMC
4667	Fan apex	Charcoal	98.5 ± 0.9 pMC
4704	Unit 2	Charcoal	340 ± 130
4705	Unit 3	Soil	750 ± 100
4668	Upper Unit 3	Charcoal	1190 ± 110
4712	Upper Unit 3	Charcoal	1300 ± 170
4710	Basal Unit 3	Charcoal	2840 ± 150
4706	Unit 4	Soil, alkali washed	3430 ± 140
4711	Unit 4	Soil	4230 ± 160
4665	Top Unit 4	Charcoal (tree root)	4290 ± 100
4713	Middle Unit 4	Soil	5270 ± 210
4709	Unit 5	Soil	12,390 ± 380
4707	Unit 6	Soil	21,970 ± 290

DISCUSSION OF AMS DATING RESULTS

Although the samples used for the AMS dating were not the same as those for the radiometric work, they were selected from the same exposures and, in most cases, at or near the original sites. Thus, the two sets of dates are not strictly equivalent, but can be compared because they are from the same stratigraphic units. Tables 3 and 4 clearly show that the AMS dates on fine-grained charcoal, given the full pretreatment described above, are significantly older than the equivalent radiometric dates on conventionally pretreated macroscopic charcoal (Table 1, 2; Fig. 2, 3).

Taking the set of dates from SMU 2 at Wangrah Creek as an example (Table 3), it is clear that the chlorate oxidation has the effect of releasing more humic material from charcoal than has already been extracted with alkali. Humic acids extracted after oxidation here have about the same age as the traditional alkali-extracted humics, which indicates that charcoal pretreated in the traditional way will not yield the correct age. These dates may result from a size-dependent age effect, as demonstrated for fluvial charcoal by Blong and Gillespie (1978). We think that the major factor involved is the more rigorous chemical pretreatment given to the AMS samples, because the dates on the <63 μm and >300 μm fractions are virtually identical (NZA-753, -746 and -747, -754). In all Wangrah Creek samples measured, the humic acid dates are younger than the residual oxidized charcoal.

At Lanyon, we again find that the fine-grained charcoal given the full pretreatment sequence are significantly older than the minimally pretreated charcoal or bulk organic samples dated radiometrically. Age differences between ^{14}C dates of humic acids and residual charcoal are variable in both magnitude and direction. Unit 3 has variable $\delta^{13}C$ values, with the acid- and alkali-extracted residue younger than the humic acid dates. In Unit 4, the oxidized residue is older than the humic acid date, and in Unit 5, there are no consistent age differences or $\delta^{13}C$ values.

TABLE 3. AMS Dates From Wangrah Creek

NZA-no.	Location	Fraction dated	$\delta^{13}C$	Age (yr BP)
749	Upper Unit 2	Humic acids	–25.4	2750 ± 100
751	Upper Unit 2	Humic acids after oxidation	–25.6	2970 ± 100
753	Upper Unit 2	Charcoal after oxidation (<63 μm)	–25.3	3225 ± 85
746	Upper Unit 2	Charcoal after oxidation (>300 μm)	–25.5	3550 ± 150
752	Lower Unit 2	Humic acids after oxidation	–25.7	3700 ± 110
750	Lower Unit 2	Humic acids	–25.7	3940 ± 110
747	Lower Unit 2	Charcoal after oxidation (>300 μm)	–25.8	4220 ± 110
754	Lower Unit 2	Charcoal after oxidation (<63 μm)	–25.1	4250 ± 90
481	Top of Unit 3	Humic acids	–24.6	8130 ± 110
566	Top of Unit 3	Residue after oxidation	–24.5	8840 ± 130
500	Middle of Unit 3	Humic acids	–24.5	8890 ± 140
543	Middle of Unit 3	Residue after oxidation	–25.0	10,720 ± 130
497	Middle of Unit 3	Humic acids	–24.4	9550 ± 110
544	Middle of Unit 3	Residue after oxidation	–23.9	11,740 ± 270
482	Low in Unit 3	Humic acids	–24.9	9830 ± 130
545	Low in Unit 3	Residue after oxidation	–23.9	12,420 ± 150

TABLE 4. AMS Dates From Lanyon

NZA-no.	Location	Fraction dated	$\delta^{13}C$	Age (yr BP)
321	Top of Unit 3	Residue after acid and alkali	–24.7	1135 ± 95
318	Top of Unit 3	Humic acids after oxidation	–24.9	1555 ± 110
244	Top of Unit 3	Humic acids	–21.5	1640 ± 195
317	Middle Unit 3	Humic acids after oxidation	–25.1	1995 ± 175
320	Top of Unit 4	Humic acids	–23.5	6580 ± 115
498	Top of Unit 4	Residue after oxidation	–23.6	6870 ± 110
483	Top of Unit 5	Humic acids	–21.0	7630 ± 120
490	Top of Unit 5	Residue after oxidation	–21.3	8830 ± 130
324	Middle Unit 5	Residue after oxidation	–21.6	9040 ± 185
319	Middle Unit 5	Humic acids	–21.1	9860 ± 150
495	Base of Unit 5	Residue after oxidation	–25.1	17,650 ± 190
501	Base of Unit 5	Humic acids	–25.0	18,290 ± 200

CONCLUSIONS

The more thorough chemical pretreatment used on the AMS samples in this work yields a more consistent chronology, with no inversions or other anomalies at either site studied. The use of oxidation is shown to be necessary for the complete removal of humic materials, even when the traditional alkali extraction has been used. It is intriguing to think that more information may be available from the study of the different humic fractions using both ^{14}C and ^{13}C values, which may lead to a better understanding of the mechanisms by which our original charcoal in sediment is contaminated by younger or older mobile organic carbon. Our results have important implications for ^{14}C dating all alluvial sediment sequences, because we have shown that the traditional pretreatment chemistry is not adequate. Related work on other sites with different lithologies and sediment characteristics indicates that the more rigorous pretreatment methodology described here is useful for ^{14}C dating of many types of low-carbon environments (Gillespie 1990; Gillespie *et al.* 1991, 1992).

The AMS chronology of Lanyon and Wangrah Creek, together with detailed stratigraphic descriptions, demonstrate that aggradation during the Holocene was relatively continuous over several thousands of years, and at Wangrah Creek, the phases of aggradation were separated by shorter periods of gully erosion. The dominance of aggradation is in contrast to the K-cycle model of rapid valley aggradation during phases of hillslope instability separated by long, stable periods of pedogenesis (Butler 1959, 1967). The stratigraphy at Wangrah Creek suggests that valley aggradation was the result of efficient trapping of sediment in swampy valley floors under stable conditions, and that instability in the landscape was manifest in the periods of gully erosion (Prosser, Chappell & Gillespie, ms.). It is not possible to determine, from the Lanyon and Wangrah Creek sites alone, if aggradation was synchronous across the region, particularly as the sites are from quite different geomorphic positions. This question will have to await accurate ^{14}C dating of additional sites.

References

Blong, R. J. and Gillespie, R. 1978 Fluvially transported charcoal gives erroneous ^{14}C ages for Recent deposits. *Nature* 271: 739–741.

Butler, B. E. 1959 Periodic phenomena in landscapes as a basis for soil studies. *CSIRO Soil Publication*. 14: 25, Canberra.

_____1967 Soil periodicity in relation to landform development in Southeastern Australia. *In* Jennings, J. N. and Mabbutt, J. A., eds. *Landform Studies From Australia and New Guinea*. Canberra, ANU Press: 231–255.

Clark, R. L. (ms.) 1983 Fire history from lake and swamp sediments: Unpublished Ph.D. thesis, Australian National University, Canberra.

Gillespie, R. 1990 On the use of oxidation for AMS sample pretreatment. *In* Yiou, F. and Raisbeck, G. M., eds., Proceedings of the 5th International Conference on Accelerator Mass Spectrometry. *Nuclear Instruments and Methods* B52: 345–347.

Gillespie, R., Magee, J. W., Luly, J. G., Dlugokencky, E., Sparks, R. J. and Wallace, G. 1991 AMS radiocarbon dating in the study of arid environments: Examples from Lake Eyre, South Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 84: 333–338.

Gillespie, R., Hammond, A. P., Goh, K. M., Tonkin, P. J., Lowe, D. C., Sparks, R. J. and Wallace, G. 1992 AMS radiocarbon dating of a Late Quaternary tephra site at Graham's Terrace, New Zealand. *Radiocarbon*, this issue.

Gray, J. 1965, Extraction Techniques. *In* Kummel, B. and Raup, D., eds., *Handbook of Paleontological Techniques*. San Francisco, W. H. Freeman and Co.: 530–586.

Knox, J. C. 1983 Responses of river systems to Holocene climates. *In* Wright, H. E. Jr., ed., *Late Quaternary Environments of the United States Vol. 2, The Holocene*. Minneapolis, University of Minnesota Press: 26–41.

Mullins, D. J. (ms.) 1985 Threshold and climatic implications of recent accumulation of sediments in an alluvial fan near Canberra. Unpublished B.Sc. (Hons) thesis, University of NSW, Kensington.

Patton, P. C. and Schumm, S. A. 1981 Ephemeral-stream processes: Implications for studies of Quaternary valley fills. *Quaternary Research* 15: 24–43.

Prosser, I. P. 1987 The history of Holocene alluviation in South Eastern Australia. *Search* 18: 201–202.

_____(ms.) 1988 Drainage basin denudation during the Late Quaternary, at Wangrah Creek, NSW. Unpublished Ph.D. thesis, Australian National University.

_____1991 A comparison of past and present episodes of gully erosion at Wangrah Creek, Southern Tablelands, New South Wales. *Australian Geographical Studies* 24: 134–154.

Prosser, I. P., Chappell J. M. A. and Gillespie R. (ms.) Episodic valley aggradation and degradation during the Holocene under conditions of low sediment supply. Submitted to *Geological Society of America Bulletin*.

Schick, A. P. 1974 Formation and obliteration of desert stream terraces: a conceptual analysis. *Zeitschift für Geomorphologie, Supplementary Band* 21: 88–105.

Singh, G. 1981 Late Quaternary pollen records and seasonal palaeoclimates of Lake Frome, South Australia. *Hydrobiologia* 82: 417–430.

Williams, M. A. J. 1978 Late Holocene hillslope mantles and stream aggradation in the Southern Tablelands of New South Wales. *Search* 9: 96–97.

Young, R. W. and Nanson, G. C. 1982 Terrace formation in the Illawarra Region of N.S.W. *Australian Geographer* 15: 212–219.

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LIQUID SCINTILLATION COUNTER CHARACTERIZATION, OPTIMIZATION AND BENZENE PURITY CORRECTION

F. G. McCORMAC

The Queen's University of Belfast, School of Geosciences, Palaeoecology Centre
Belfast BT7 1NN, Northern Ireland

ABSTRACT. In liquid scintillation counting (LSC), small variations in benzene purity can cause ^{14}C pulse-height spectra to move with respect to the counting window. Thus, one must carefully monitor the purity of each benzene sample and apply corrections for spectral shifts. I describe here the techniques used at Queen's University Belfast for deriving correction factors for observed small variations in benzene purity. I also describe the methods used at our laboratory to fine-tune our Quantulus LS counters for high-precision dating. The tuning of the instruments minimizes the effect of fluctuations in gain that may occur during the long counting periods required for high-precision dating. Any remaining influences on efficiency owing to gain changes are corrected for, along with the purity correction, by continuous monitoring of the spectrum produced by the external source.

INTRODUCTION

The accurate and precise measurement of the weak β^- radiation used in ^{14}C dating requires that carbon from the sample be converted, with a high efficiency, into a medium from which low-level radiation detection is possible, *e.g.*, benzene, in the case of liquid scintillation counters (LSCs) and acetylene, methane or carbon dioxide, in the case of gas counters. Counters (either LS or gas proportional) suitable for the accurate and precise measurement of the weak β^- radiation are specially designed to give high-detection efficiency, long-term stability and low background contributions. Despite great technical advances in LSC design, errors at the counting stage of the dating process can still arise from impurities in the synthesized benzene. Using a commercially available chromium-activated cracking catalyst, Switsur and Waterhouse (1989) analyzed the impurities in benzene produced by cyclotrimerization of acetylene. Although they showed the levels of impurities (principally, ethylbenzene, toluene, acetone, (1-methylpropyl)benzene and isopropylbenzene) to be small (86 ppm or less, see also Polach, Gower & Fraser 1973; Coleman *et al.* 1973; Tamers 1975; Witkin *et al.* 1991), this study shows that, even at such low levels, impurities can contribute to dating errors, particularly for older material. Impurities affect the measured activity of a sample by causing shifts in the resultant energy spectrum, thereby reducing the counting efficiency within a given counting window. Birks (1970) showed that the concentration of dissolved oxygen also affects the degree of quenching. Thus, vials filled at different ambient temperatures and pressures are quenched by different amounts, even if the benzene has identical impurity levels at the outset. It is important that spectral shifts caused by all forms of quenching are corrected for in high-precision dating. Described here is a method for the monitoring and correction of spectral shifts caused by variable quenching of benzene containing low levels of impurities. Because small gain changes in LSCs can also affect the efficiency during the long counting periods required for high-precision measurements, we quasi-continuously monitor the external source spectrum and correct for gain changes along with the purity correction (*i.e.,* purity variation causes a primary spectral shift and gain changes result in spectral variation about the offset level).

LIQUID SCINTILLATION COUNTERS

The LSCs used at Queen's University, Belfast are LKB Quantulus 1220s. These instruments have been modified by the manufacturer so that the automatic gain control on the left and right phototubes can be overridden and the high voltages can be set independently on either phototube.

The modification also provides for a single manual high-voltage adjustment on the guard phototubes. The principle behind the automatic gain control is that light-emitting diodes (LEDs) in juxtaposition to the phototubes flash on and off at approximately 60 Hz. Since the LEDs are carefully controlled to emit a constant light flux, the output response of the phototubes to the light from the LEDs should be constant. A feedback circuit to the high-voltage controller adjusts the high voltage to maintain a constant output from the phototubes in response to the LED light. Whereas the feedback circuitry represents a great step in technology and is labor-saving for routine ^{14}C dating, it is not used in high-precision dating. Instead, the high voltages are set manually, allowing for improved optimization and eliminating the need for the LEDs, which can thus be turned off. This reduces the exposure of the photocathodes to light, and may help prolong the life and stability of the phototubes.

Independent manual control of the high voltages requires that spectra from the left and right tubes be determined independently and the high voltages adjusted so that the two match exactly. The spectra may not be optimally matched in the instrument as supplied, and the flexibility introduced by manual control allows for improved optimization. Optimization of the left and right tubes can be performed in several ways. We generate two graphs (one for each phototube), which give the internal spectral quench parameter, SQP(I) (this is the channel position of the center of gravity of the ^{14}C β^- spectrum from a high activity (1692 dpm/g) ^{14}C benzene sample), as a function of high voltage (details of selection of left and right spectra are given in the LKB service manual under Section F, spectra adjustment). By recording SQP(I) as a function of high voltage for each tube (see Fig. 1), two linear graphs are obtained and a regression line is fitted to each. From this, high voltages are determined for identical SQP(I) values, and the spectra can be matched. LKB set SQP(I) to 407 ± 1 for both tubes.

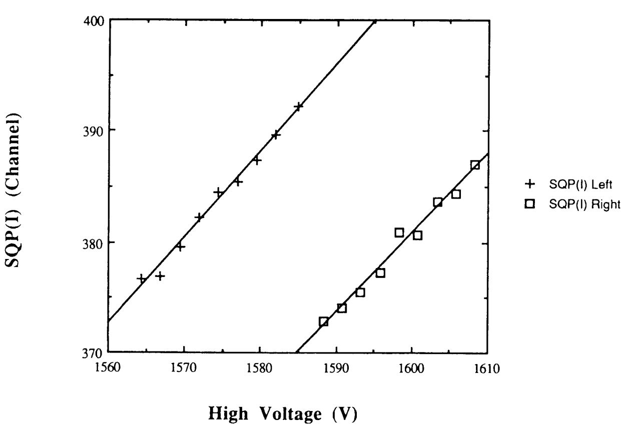

Fig. 1. Graph of SQP(I) *vs.* high voltage for both left and right phototubes independently

It is important that SQP(I) is used to match the left and right phototube spectra, and not SQP(E). SQP(E) is the channel above which 1% of the observed counts are obtained when the 10 μg ^{226}Ra (3.7 KBq) external source is presented to the base of the vial. Since the dynamic response of the tubes as a function of β^- energy are not identical and the Compton continuum produced by the ^{226}Ra source is quite dissimilar from the ^{14}C spectrum, significant offsets between left and right external spectra may occur at the higher energy levels, even though the ^{14}C spectra are well matched.

Balance-Point Counting

Surface water used in our benzene synthesis (Barker 1953) contains ^3H, which is incorporated into the synthesized benzene (Pearson 1983). Because of overlap of the ^3H (maximum β^- energy of 0.018 MeV) and ^{14}C (maximum β^- energy of 0.156 MeV) energy spectra, it is not possible to use all β^- decays within the energy range emitted by ^{14}C for ^{14}C dating. Instead, a lower energy discriminator is defined, so that the contribution of ^3H to the final ^{14}C counts is minimal (<1% of the total ^3H, see below).

The simplest measure of instrument performance is provided by the Figure of Merit (E^2/B), where E is the observed counting efficiency, and B, the background count rate. If the goal, as is often the case in radioisotope measurement, were to maximize the Figure of Merit, then all disintegrations detected with energy above the lower-discriminator up to the maximum energy of β^- emission for ^{14}C could be used in determining the activity of a sample. However, accuracy and precision require long-term instrument stability; thus, it is considered judicious to sacrifice counts at the higher β^- energies to operate the counter at 'balance-point'. Operating at 'balance-point' requires that an upper-level discriminator be defined, such that the counts recorded in a sample at the lower-discriminator channel are approximately equal to the counts recorded at the upper-discriminator channel. During a counting period, the effect of small fluctuations in system gain, that result in ^{14}C spectral shifts around the balance-point position are then minimized. As the spectrum moves within the counting window, counts that are lost at one side of the spectrum are gained at the other, resulting in only slightly reduced total counting efficiency. It is important to note that balance-point operation does not provide a constant counting efficiency, but only reduces the effect that small system gain changes have on the efficiency (Pearson 1979).

Any external factor that causes a change in the pulse-height spectrum will result in a ^{14}C spectrum moving with respect to the balance-point position. Thus, it is necessary to normalize all spectra by applying an appropriate correction to the counts obtained in the ^{14}C window, thereby simulating a constant efficiency. (I describe below corrections for spectral shifts caused by quenching and other factors (such as photomultiplier gain changes) that affect the pulse-height spectrum and shift the mean position of the spectrum in the counting window.)

Tritium Interference

^3H is incorporated into the benzene primarily by reacting water with lithium carbide to generate acetylene. The acetylene is subsequently trimerized on a chromium catalyst to produce benzene by a method similar to that described by Noakes, Kim and Stipp (1965). Although considerable efforts have been made to locate and use a water source with a low ^3H content, some ^3H is still present in the final benzene (Pearson 1983). Because the high energy end of the ^3H spectrum overlaps the low energy end of the ^{14}C spectrum, a contribution from ^3H exists in the final ^{14}C count rate. To minimize this and retain as much as possible of the ^{14}C β^- counts, the lower energy discriminator is set, so that only 1% of the ^3H is included in the final ^{14}C spectrum. The 1% level is determined by obtaining the spectrum of a tritiated benzene sample and determining the energy level (channel), above which only 1% of the ^3H counts is recorded. About 8% of ^{14}C β^- decays are lost by positioning the lower discriminator at this level (see Pearson 1979).

Determination of Upper Discriminator for Balance Point Operation

To operate at balance point, one must first determine the lower energy discriminator level as described above. Then, using a high-activity ^{14}C benzene sample (1.692×10^3 dpm/g in our case), an energy spectrum is recorded for 100 min. The spectrum, which is in counts per minute (cpm) as a function of log (energy), is then used to determine the upper discriminator level by locating the channel where the count rate equals that in the lower discriminator channel. The count rate at the lower discriminator channel is taken as the mean of five channels on either side of the lower discriminator. Thus, the upper discriminator channel is determined by taking an 11-point running mean of the counts in the higher energy channels and finding the channel for which the running mean value at the higher energy equals that at the lower discriminator. For our Quantulus counters, the channel separation between lower and upper discriminators (*i.e.*, ^{14}C counting window) is about 275 channels.

Determination of the Correction Factor

When both left and right phototubes have been matched, and the upper and lower level discriminators have been determined, it is then possible to proceed to determine the normalization constants to simulate a constant efficiency. A parameter that accurately monitors the position of the spectra in the Quantulus counters is the SQP(E) value (*i.e.*, the channel above which 1% of the observed counts from the Compton continuum is obtained when the 10 μg ^{226}Ra (3.7 KBq) external source is presented to the base of the vial). We monitor SQP(E) for 10% of the sample counting time (*i.e.*, 10 min for every 100-min counting period). By determining the change in efficiency as a function of SQP(E) for a fixed counting window, and monitoring SQP(E) for each sample, one can correct for efficiency variations caused by intersample quench variability (*i.e.*, a quench correction curve). Because the purity of the benzene we synthesize is very high, the quench corrections are small, and thus, we cannot determine a quench correction curve with sufficient accuracy from a set of quenched standards. Thus, we simulate the standards by slightly altering the high voltages on the phototubes (during setup) and recording the SQP(E) values for high-activity spectrophotometric benzene as a function of high-voltage (*i.e.*, we alter the high voltage by ±5 V to simulate a gain change). The high voltage on both left and right tubes is adjusted by *ca.* 1 V at a time (the exact voltage adjustment for left and right tubes is determined from the regression line in Figure 1, to ensure that the spectra remain matched (*i.e.*, have equal SQP(I) values) as the high voltages are varied).

The ^{14}C spectra and associated SPQ(E) values recorded at the range of high voltages are stored for subsequent computer analysis. A computer program that passes a window, identical in width to the balance-point window, over each of the spectra and sums the counts within the window for each channel step, is used to determine the position of maximum efficiency for each spectrum. The lower-discriminator channel at maximum efficiency is noted for each spectrum. A graph is then plotted of SQP(E) as a function of lower discriminator channel (Fig. 2).

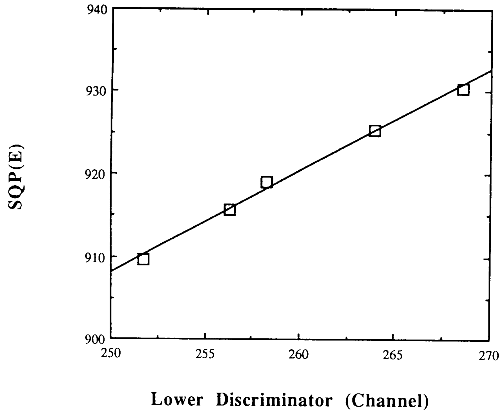

Fig. 2. Lower discriminator channel as a function of SQP(E)

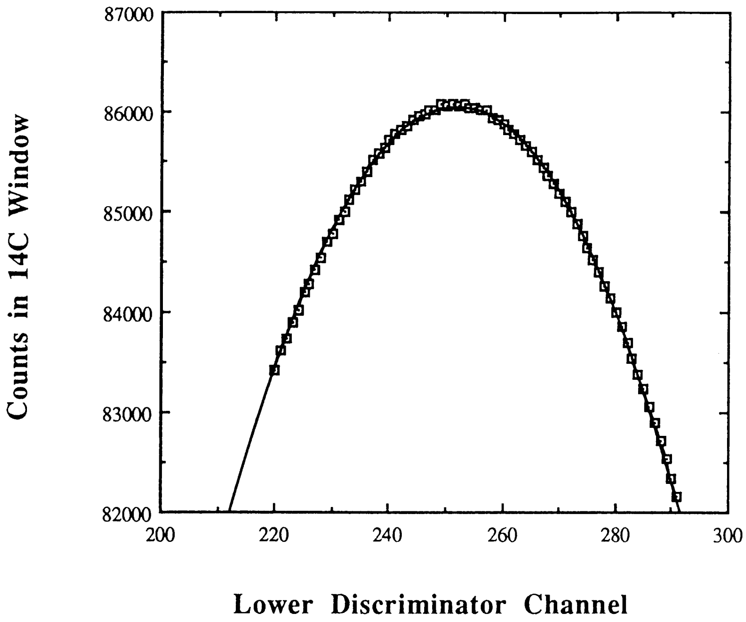

Fig. 3. Counts within ^{14}C counting window as a function of lower discriminator channel. □ = individual data points; a parabolic curve is fitted to the data.

The high voltages are set at their operating levels and a ^{14}C spectrum obtained from the high-activity standard. The spectrum is input to the computer program, which steps the counting window, one channel at a time, through the spectrum, and a plot of total counts within the window as a function of lower discriminator channel is generated (Fig. 3). The lower discriminator channel, which forms the abscissa of Figure 3, is converted to SQP(E), with the results obtained in Figure 2 giving a graph of counts *vs.* SQP(E) (Fig. 4). An orthonormalized Legendre polynomial of order 2 (*i.e.*, a parabola) is fitted to the data in Figure 4, and the peak of the parabola is determined in terms of SPQ(E)

$$SQP(E)_{bal} = \frac{-b}{2a} \tag{1}$$

where a and b are the coefficients of the x^2 and x terms in the polynomial, respectively. The total counts at this position represent the maximum counting efficiency of the matched balance-point spectrum. To determine a correction for SQP(E) variations in sample benzene, we use the following formula

$$\text{Correction factor} = \frac{aSQP(E)^2_{bal} + bSQP(E)_{bal} + c}{aSQP(E)^2_{sample} + bSQP(E)_{sample} + c} \tag{2}$$

where a, b and c are the coefficients determined from the Legendre polynomial fit, $SQP(E)_{bal}$ is the external spectral quench parameter for a balance point spectrum and $SQP(E)_{sample}$ is the external spectral quench parameter for a sample spectrum. The cpm/g is multiplied by the correction factor after the background has been subtracted. Figure 5 shows correction factors as a function of SQP(E) for one of our counters. This curve should be determined for each individual counter and needs to be reevaluated about every three months or after any change is made to the operating voltages or settings.

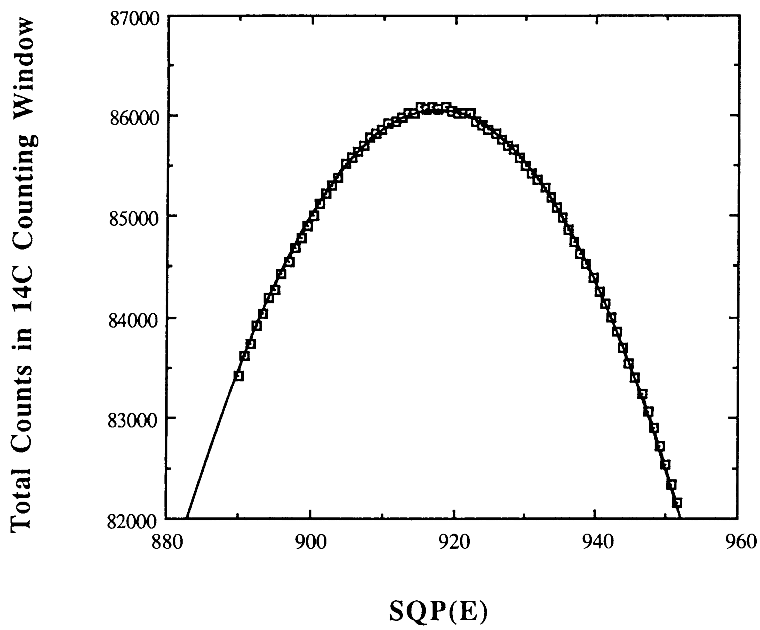

Fig. 4. Counts within ^{14}C counting window as a function of SQP(E). See Figure 3, for symbols.

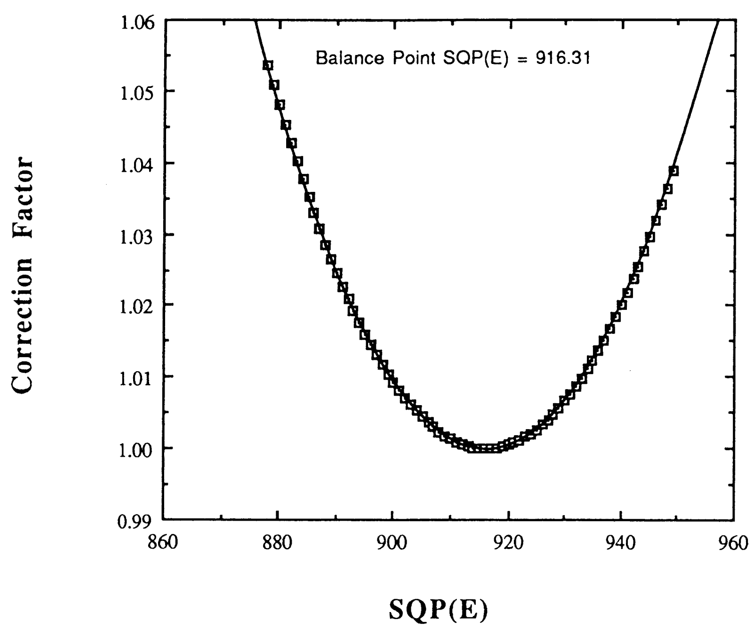

Fig. 5. Correction factor by which counts within counting window should be multiplied as SQP(E) varies

Effect of Spectral Shifts on Age Determination

The SQP(E) correction factor described above can be expressed as an error on the ^{14}C age. Figure 6 gives the age corrections (*i.e.*, the age by which the determined date would be too old if no correction was applied) for each channel difference in SQP(E) from that determined with the active standard used during setup. As can be seen in Figure 6, very small purity changes result in a negligible error on the final date. However, significant biases are introduced at >2 channels shift

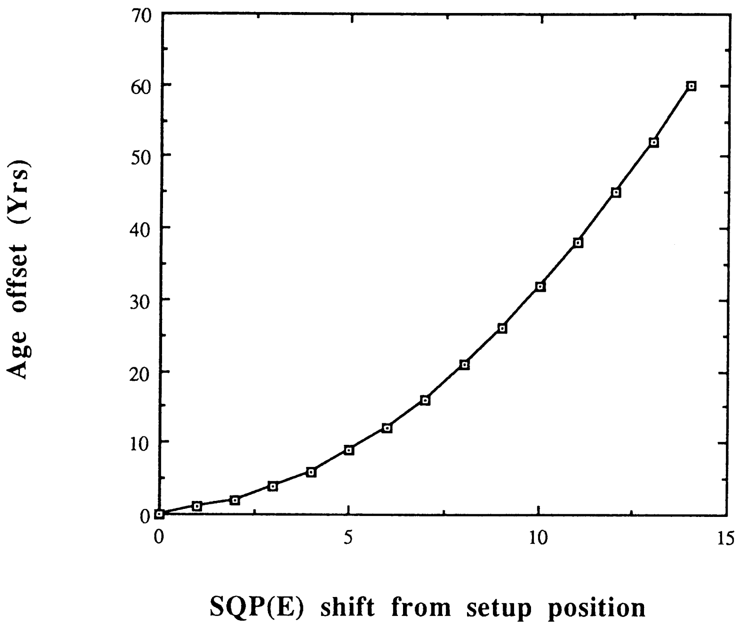

Fig. 6. Error in ^{14}C age as a function of SQP(E) if purity and gain variations are not corrected for

in SQP(E). We have confirmed the results obtained in Figure 6 by dating a highly quenched benzene sample derived from charcoal obtained at an archaeological site in north Antrim, Northern Ireland. The date for the sample was 4051 ± 24 BP. Had no correction for quenching been applied to the counts from this sample, the resultant date would have been 4112 ± 24 BP. The sample was vacuum-distilled to remove impurities and recounted. The new date determined was 4062 ± 21 BP, with only a small correction needed for quenching. Thus, within the error limits, the correction factor had satisfactorily accounted for the quenching.

Because the background is not uniform with energy, when a ^{14}C spectrum shifts with respect to the counting window, it is subject to a different background contribution. This variation in background can significantly affect the result when dating very old samples, at *ca.* 50 ka. To investigate the effect of purity changes on background contribution, we used an accumulated background spectrum to compute the total counts within the counting window as a function of SQP(E) (the method was identical to that described above for the ^{14}C spectrum). By determining the total counts within the background counting window at balance point, and normalizing to this value, we determined a multiplier for the background as a function of SQP(E) (Fig. 7). For material in the 40 to 50 ka range, application of the background correction can alter the date by as much as 1 ka depending on the background level. For more recent samples (*e.g.* 0–10 ka), the error is again background- level-dependent, but usually <2 a.

Conclusions

I have presented methods used to characterize and optimize LSCs at The Queen's University of Belfast. Although the description relates to LKB Quantulus instruments and terminology, the principles outlined are identical for other LSC types. If high-precision dating is to be attempted, it is vital that the LSC is:

1. Operated at balance-point for long-term stability, low background and optimal efficiency (within the constraints of balance-point counting)

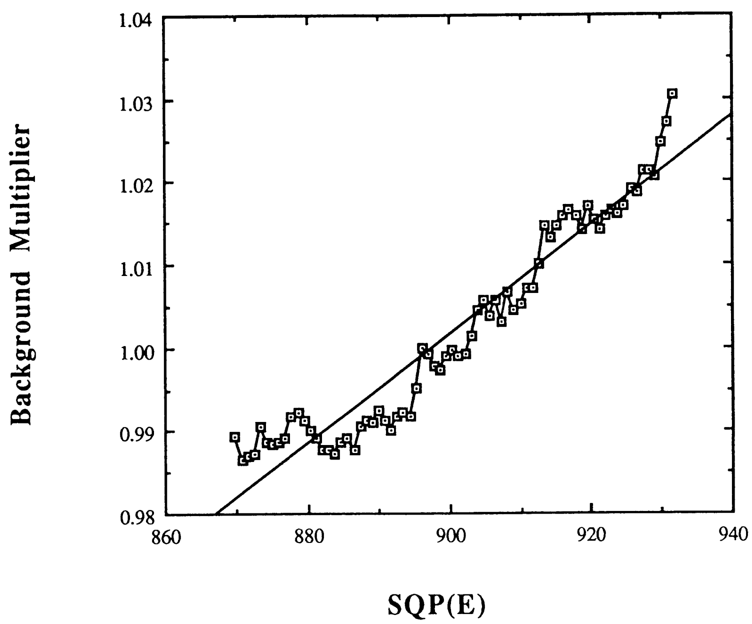

Fig. 7. Background multiplier as a function of SQP(E). The straight line represents a linear regression fit to the background multiplier. The data points are the individual background multiplier values determined by normalizing the counts within the counting window at a particular SQP(E) value to the counts in the counting window at balance-point.

2. Characterized in terms of the spectral shifts of each phototube as a function of high-voltage, so that the spectra from left and right phototubes are matched and remain so
3. Characterized to correct for spectral shifts resulting from variation in benzene purity due to 1) alkylbenzenes introduced during the trimerization process, 2) varying dissolved oxygen levels in the benzene due to ambient temperature and pressure variations during vial filling, and 3) instrument gain changes.

It is of utmost importance in high-precision dating to apply corrections for spectral shifts resulting from variable levels of quenching in synthesized benzene and for instrument gain changes. Without these corrections, errors in excess of 60 a on material from the past 10 millennia, and in excess of 1 ka on material in the 40 to 50 ka range (depending upon background levels) can occur.

Acknowledgments

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REFERENCES

Barker, H. 1953 Radiocarbon dating: Large scale preparation of acetylene from organic material. *Nature* 172: 631–632.

Birks, J. B. 1970 Physics of the liquid scintillation process. *In* Bransome, E. D., ed., *The Current Status of Liquid Scintillation Counting*. New York, Grune and Shatton.

Coleman, D. D., Liu, C. L., Dickerson, D. R. and Frost, R. R. 1973 Improvement in trimerisation of acetylene to benzene for radiocarbon dating with a commercially available vanadium oxide catalyst. *In* Rafter, T. A. and Grant-Taylor, T., eds., *Proceedings of the 8th International ^{14}C Conference*. Wellington, Royal Society of New Zealand 1: 158–170.

Noakes, J. E., Kim, S. M. and Stipp, J. J. 1965 Chemical and counting advances in liquid scintillation age dating. *In* Olsson, E. A. and Chatters, R. M., eds., *Proceedings of the 6th International Conference on Radiocarbon and Tritium Dating*. Clearinghouse for Federal Scientific and Technical Information, Washington, DC: 68–92.

Polach, H., Gower, J. and Fraser, I., 1973 Synthesis of high purity benzene for radiocarbon dating. *In* Rafter, T. A. and Grant-Taylor, T., eds., *Proceedings of the 8th International ^{14}C Conference*. Wellington, Royal Society of New Zealand, 1: B36– B49.

Pearson, G. W. 1979 Precise ^{14}C measurement by liquid scintillation counting. *Radiocarbon* 21(1): 1–21.

_____1983 The development of high precision ^{14}C measurement and its application to archaeological time-scale problems. Ph.D. thesis, The Queen's University Belfast.

Switsur, R. and Waterhouse, J. S. 1989 Benzene purity in radiocarbon dating samples. *In* Long, A. and Kra, R. S., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 260–263.

Tamers, M. A. 1975 Chemical yield optimisation of the benzene synthesis for radiocarbon dating. *International Journal of Applied Radiation Isotopes* 26: 676–682.

Witkin, D., Rigali, M. J., Kalin, R. M., Nagy, B. and Long, A. 1991 Impurities arising during benzene synthesis from acetylene on vanadium and chromium catalysts. *Radiocarbon* 33(2): 261–262. Abstract.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 47–70]

HARWELL RADIOCARBON MEASUREMENTS XI

M. A. HARDIMAN, J. E. FAIRCHILD and GEOFFREY LONGWORTH

Isotope Measurements Laboratory, AEA Technology Harwell, Oxfordshire, OX11 ORA, UK

INTRODUCTION

Following Harwell Measurements VIII (Walker, Williams & Otlet 1990), this is the final series of lists of English archaeological dates commissioned for measurement by the Historic Buildings and Monuments Commission (HBMC) for England within prescribed contractual periods. This list, containing 127 dates, refers to the period April 1988 to March 1990, and results are reported irrespective of whether the associated projects are completed or ongoing.

Measurement procedures were essentially as reported earlier. We used two measuring systems of the Isotope Measurements Laboratory, as appropriate to the sample size. In all cases, the error term quoted for the ^{14}C age BP is the ± 1 standard deviation (σ) based on an estimate of full replicate sample reproducibility (Otlet 1979). Calculations of ^{14}C age are based on the Libby half-life of 5568 years, with 100% modern being defined as 0.95 × the activity of NBS oxalic acid corrected for fractionation. All raw ^{14}C ages are quoted as years BP, with AD 1950 as the reference year, and are corrected for fractionation using the ^{13}C stable isotope ratio (Stuiver & Reimer 1986). Values of the ^{13}C ratios are measured in the laboratory, and are quoted as enrichment per mil relative to the PDB standard. As previously, the basic text of reports is prepared from database entries using an in-house microcomputer. National Grid References are abbreviated to NGR.

ACKNOWLEDGMENTS

We wish to acknowledge the financial support of the HBMC which funded both the sample measurements and this publication, and the cooperation of D. Jordan of the Ancient Monuments Laboratory (English Heritage) (AML). We also acknowledge the work of R. L. Otlet, who was laboratory manager until March 1990, A. J. Walker, who supervised the measurement work until June 1990, and all staff members, past and present, who worked to produce the results listed below.

ARCHAEOLOGICAL SAMPLES

Alfriston series

2540 ± 70

HAR-941. ALF 2 $\delta^{13}C = -23.3‰$

Bone, AML 749202, from northwest quadrant mound, Layer 2 at Alfriston, Sussex (50°48′49″N, 00°08′27″W, NGR TQ 508 038). Collected Aug. 1974 and submitted Oct. 1974 by P. L. Drewett, Institute of Archaeology, University of London (Drewett 1975, 1982).

2530 ± 70

HAR-2650. 1483 $\delta^{13}C = -23.0‰$

Bone, AML 7716310, from a circular storage pit associated with probable early saucepan pottery at Marc 3, R17, Winnal Down. Collected May 1977 and submitted Nov. 1977 by P. Fasham, The Trust for Wessex Archaeology.

Shrewton series

HAR-4830. SNDRFRC4 **4100 ± 100**
$\delta^{13}C = -20.5‰$

Antler, red deer, from Pit 1, Shrewton (51°12′07″N, 01°52′23″W, NGR SU 0887 4480). Submitted Jan. 1982 by S. Rollo-Smith, The Trust for Wessex Archaeology.

Comment (S.R.-S.): This date is earlier than anticipated for the grave goods, which could not be earlier than 4 k BP. The result is earlier than any other from the barrow cemetery and contemporary with dates from the Stonehenge ditch, cursus and the destruction of the lesser cursus. The ditch fill contained small sherds of All-Over-Corded (AOC) Beaker, and antler fragments occurred throughout the central gravefill. I believe that the AOC sherds and antler are residual and that earlier material was incorporated into the gravefill, to which the ^{14}C date refers (Green & Rollow-Smith 1984).

Potterne series

HAR-8938. POTT16 **3000 ± 90**
$\delta^{13}C = -25.6‰$

Charcoal, AML 874369, from fill 3716 of post-pit 3605 at Potterne, near Devizes, Wiltshire (51°19′50″N, 2°00′21″W, NGR ST 996 591). Collected Aug. 1984 and submitted May 1987 by C. Gingell, The Trust for Wessex Archaeology (Gingell & Lawson 1984, 1985).

Comment (C.G.): Result will date the occupation features underlying the midden. For a plan of these features, see Gingell and Lawson (1985).

Field Farm series

HAR-9140. W109R625 **3690 ± 100**
$\delta^{13}C = -28.8‰$

Charcoal, identified as *Corylus* and *Prunus*, AML 881212, from fill of a Deverel-Rimbury cremation urn with a smaller ring ditch (604, ~75 m northeast of ring ditch (417) at Field Farm, Burghfield, Berkshire (51°25′41″N, 1°1′44″W, NGR SU 675 704) (Butterworth & Lobb, in press).

Comment (S.J.C.): Result provides a relative date for the construction of the ring ditch and dates the urn type (Deverel-Rimbury). One of a series of four dates from the site (HAR-9139, -9142 and -9143).

Dorchester By-pass series

HAR-9160. 186SF100 **3200 ± 90**
$\delta^{13}C = -24.8‰$

Bone, identified as human, adult male, from an inhumation cut into the base fills of a boundary ditch that cuts across the southeast side of an Early/Middle Bronze-Age (E/MB) enclosure at Middle Farm (50°42′26″N, 2°27′47″W, NGR SY 6730 8990). Dated from a pottery assemblage. Collected July 1987 by M. Fletcher; submitted Nov. 1987 by P. J. Woodward, The Trust for Wessex Archaeology (Green 1987).

Comment (P.J.W.): The date falls within the range for Bronze-Age settlements and boundaries for Dorset, such as at Poundbury (HAR-994, Shearplace Hill (Rahtz & ApSimon 1962), HAR-5698, Rowden). HAR-9160 provides an early date for the dykes and boundaries in the area, some of which underlie and antedate the hillforts of Maiden Castle and Poundbury.

Gnipe Howe series

Samples from Gnipe Howe, Hawkser, Whitby, Yorkshire (54°51'00"N, 1°13'53"W, NGR NZ 4934 5086). Collected Jan. 1972; submitted Aug. 1985 by A. E. Finney, East Riding Archaeology Committee.

HAR-8773. GHRBQB2 — **3440 ± 90**; $\delta^{13}C = -28.1‰$

Charcoal associated with Urn III and found in Quad B, resting on stones of a cairn and sealed by a final capping mound at Gnipe Howe Round barrow.

Comment (A.E.F.): Result provides an independent date for pot and its contents as well as for final sealing of the mound.

HAR-8774. GHRBQB3 — **3910 ± 150**; $\delta^{13}C = -28.1‰$

Charcoal associated with many fragments of a pot (Urn II) in undisturbed soil, sealed by a final capping mound at Gnipe How Round Barrow.

Comment (A.E.F.): Deposit also contained flint flakes showing traces of burning. Dates final capping of the mound.

Kemp Howe series

Samples from Kemp Howe, Cowlam, Near Driffield, Yorkshire (54°21'25"N, 00°58'47"W, NGR SE 663 962). Collected 1968; submitted Aug. 1985 by A. E. Finney.

HAR-8776. KHT6GIBI — **1310 ± 100**; $\delta^{13}C = -22.0‰$

Bone, right tibia and femur (human), from Grave 1m, Burial 1 of Anglian cemetery.

Comment (A.E.F.): A previous date for Grave 3, Burial 3, gave an earlier-than-expected result. This result confirms the earlier dating. No associated grave goods.

HAR-8778. KHLBFBT3 — **4870 ± 90**; $\delta^{13}C = -27.1‰$

Charcoal from facade bedding trench, associated with occupation debris used as packing for post-holes.

Comment (A.E.F.): Facade was part of an earlier phase at Kemp Howe, which included a mortuary enclosure. The date should be compared with that for Long Barrow ditches.

HAR-8780. KHRBDE31 — **3730 ± 70**; $\delta^{13}C = -22.6‰$

Red deer antler, from primary fill of Round Barrow ditch.

Raisthorpe Manor series

5070 ± 60

HAR-8783. RMLBFBT3 $\delta^{13}C = -26.0‰$

Charcoal from the upper level of facade bedding Trench 3, Section E, at Raisthorpe Manor Long Barrow, Raisthorpe Manor Thixendale, near Burdsel, North Yorkshire (54°03′01″N, 00°41′55″W, NGR SE 852 624). Collected March 1965; submitted Aug. 1985 by A. E. Finney.

Comment (A.E.F.): Dates period of use of bedding trench and related features of the mortuary enclosure, pavement, *etc.*

Seamer Moor series

Two charcoal samples from Seamer Moor Barrow near Scarborough, Yorkshire (54°15′39″N, 00°26′04″W, NGR TA 0196 8617).

5260 ± 100

HAR-8785. SMT3SN2 $\delta^{13}C = -26.0‰$

Charcoal from *in-situ* red stones near Hearth Barrow 1. Collected Sept. 1966; submitted Aug. 1985 by A. E. Finney.

Comment (A.E.F.): Hearth is sealed by mound, thus sample dates final deposition of barrow mound.

4990 ± 90

HAR-8786. SMT3S01 $\delta^{13}C = -26.8‰$

Charcoal from shallow pit, Trench 3, Section 0 at Seamer Moor Barrow 1, rough moorland near Scarborough, North Yorkshire.

Comment (A.E.F.): Grave pit was excavated in 1934; as all the material was lost in the Hull bombing of 1942, this sample dates this grave pit and the other three pits not found in the 1966 excavation.

Heybridge series

2610 ± 110

HAR-4844. 813340 $\delta^{13}C = -25.7‰$

Charcoal, AML 813340, from Heybridge, site ref. F84 (51°44′29″N, 00°40′48″E, NGR TL 850 082). Collected 1972 by P. J. Drury; submitted March 1982 by N. Wickenden, Chelmsford Archaeological Trust (Wickenden 1986).

Comment (A.J.C.): At variance with HAR-4843 (from same post).

Mingie's Ditch series

1900 ± 80

HAR-4488. HYMD136 $\delta^{13}C = -27.2‰$

Charcoal from the bottom of an Iron-Age gully at Mingie's Ditch, Hardwick, Oxon. Collected Sept. 1978 and submitted May 1981 by M. A. Robinson, University Museum, Oxford.

Saint Oswald's Priory series

HAR-9700. 4175B464 **1170 ± 60**
$\delta^{13}C = -21.4‰$

Bone, AML 890025, from Gloucester (51°52′08″N, 02°14′49″W, NGR SO 830 190). Collected 1983 and submitted Nov. 1988 by C. M. Heighway, Gloucester Museum (Heighway 1978, 1980).

Comment (C.M.H.): Burial antedating Saxon minster of ~ AD 900.

Wetwang Slack series

From Wetwang, Humberside (54°01′34″N, 00°33′51″W, NGR SE 9405 5989).

HAR-8538. WK 023 **4490 ± 90**
$\delta^{13}C = -27.7‰$

Charcoal, AML 872561, from a chalk gravel matrix from one of a series of pits with Neolithic pottery (WK 008), possibly part of a linear ritual monument. Collected Aug. 1984 and submitted March 1987 by J. S. Dent, Humberside Archaeology Unit (Dent 1983).

Comment (J.S.D.): With HAR-8539 and -8540, this sample provides a series of dates for an important stage of later Neolithic ritual activity and associated pottery.

HAR-8539. WK 017 **3980 ± 100**
$\delta^{13}C = -27.8‰$

Charcoal, from same context as HAR-8538 (010). Collected Aug. 1984 and submitted April 1987 by J. S. Dent.

Comment (J.S.D.): Same as for HAR-8538.

HAR-8540. WK 031 **4340 ± 100**
$\delta^{13}C = -25.8‰$

Charcoal, AML 872562, from same context as above, HAR-8538 and -8539 (WK 009), found with pottery and flints. Collected Aug. 1984 and submitted March 1987 by J. S. Dent.

Comment (J.S.D.): This sample dates an important phase of ritual activity and material culture.

HAR-8543. WG10A0 **5670 ± 160**
$\delta^{13}C = -27.5‰$

Charcoal, AML 872559, from an early Iron-Age pit associated with pottery and part of a settlement that included a line of four round houses. Collected and submitted May 1980 by J. S. Dent.

Comment (J.S.D.): This result, which should provide an association date for early Iron-Age pottery and related roundhouse, is older than anticipated by >2 ka.

HAR-9244. WY 8AK **3690 ± 80**
$\delta^{13}C = -26.7‰$

Charcoal, AML 881271, from a Beaker-period grave, the central burial of a ring-ditch enclosure. The sample is from a layer of charcoal, presumed to be the collapsed lid, which covered both bodies. Collected Dec. 1987 and submitted June 1988 by J. S. Dent.

Comment (J.S.D.): Compare with HAR-9245 and -9247 from the same coffin.

HAR-9245. WY8AM — **3680 ± 100**; $\delta^{13}C = -26.8‰$

Charcoal, AML 881272, from the central grave of a Beaker-period funerary monument. The wood is from the upper sides of the charred inner surface of a monoxylous coffin, which contained two burials. The earlier one was disturbed by reopening. It was an inhumation carefully rearranged over the feet of the later, crouched inhumation, which was accompanied by a decorated beaker. Collected Dec. 1987 and submitted June 1988 by J. S. Dent.

Comment: HAR-9244, -9245 and -9247 date the monument and beaker, both part of the great extended cemetery of round barrows at Garton Slack.

HAR-9247. WY 8AJ — **3750 ± 80**; $\delta^{13}C = -26.9‰$

Charcoal, AML 881270, underlying the skeletons in the remains of a wood coffin, central to a circular ditch. Collected Dec. 1987 and submitted June 1988 by J. S. Dent.

Comment (J.S.D.): Date compares with HAR-9244 and -9245 for the monument and beaker.

Ling Howe series

HAR-9248. LIN84024 — **5220 ± 100**; $\delta^{13}C = -25.9‰$

Charcoal, AML 881269, from old soil beneath chalk mound material of a Neolithic long barrow at Ling Howe, Walkington, Humberside, Yorkshire Wolds (53°48′30″N, 00°32′09″W, NGR SE 964 357). Collected May 1984 and submitted June 1988 by J. S. Dent.

Comment (J.S.D.): Date provides *terminus post quem* for mound construction.

North Cave series

Samples from a previously water-logged pit in an Iron-Age and Roman settlement at North Cave, Humberside (53°47′12″N, 00°39′56″W, NGR SE 879 331). One pit had stood open as a shallow well or water hole in the Iron Age, and contained organic material as well as pottery and animal bone. Wooden steps into the well were made from a reused ox-collar and a possible rake.

HAR-10225. MS86 100 — **2160 ± 80**; $\delta^{13}C = -27.5‰$

Wood. Submitted Feb. 1989 by J. S. Dent.

Comment (J.S.D.): HAR-10226, from the same pit, is some centuries older.

HAR-10226. NC86 100 — **2410 ± 80**; $\delta^{13}C = -28.9‰$

Charcoal. Collected 1986; submitted Feb. 1989 by J. S. Dent.

Comment (J.S.D.): HAR-10225, from the same pit, is some centuries younger.

Hambledon Hill series

4270 ± 100

HAR-6037. HN82C108 $\delta^{13}C = -25.8‰$

Charcoal, AML 831452, from an undercut at site reference HN82C108, Hambledon Hill, Dorset. Collected Sept. 1982 and submitted Feb. 1984 by R. Mercer, Department of Archaeology, University of Edinburgh.

4660 ± 100

HAR-9168. HH751535 $\delta^{13}C = -26.1‰$

Charcoal, ~50% identified as hazel/alder by C. A. Keepax, not twiggy, AML 760798, from HH 75, Site D2, cross Ditch 1, Layer 11. Sample is from a primary chalk wash overlying the solid chalk base of a ditch at a Neolithic causewayed enclosure. Collected Sept. 1975 and submitted Feb. 1976 by R. Mercer.

Comment (R.M.): The silt deposit contained chalk and flint lumps and bone and antler pieces.

4140 ± 100

HAR-9169. HH751498 $\delta^{13}C = -26.4‰$

Charcoal, identified as oak/hazel/hawthorn by C. A. Keepax, AML 760797, from HH 75 Site F, from a causewayed enclosure ditch, Layer 6. Collected Sept. 1975 and submitted Feb. 1976 by R. Mercer.

Comment (R.M.): Layer 6 consists of dark brown soil, chalk lumps and large flint nodules filling a roughly V-shaped slot recut into ditch fill; the deposit is associated with flintwork, pot and axe fragments.

Trelan series

3970 ± 120

HAR-5280. 41-203 $\delta^{13}C = -25.0‰$

Charcoal, from Trelan II, Cornwall (50°01′48″N, 05°09′52″W, NGR SW 734 193).

Westward Ho! series

6110 ± 160

HAR-5632. 8311026 $\delta^{13}C = -27.1‰$

Charcoal, AML 8311026, from the upper levels of a Mesolithic midden at Westward Ho!, Devon (50°53′18″N, 04°29′59″W, NGR SS 242 129).

Stanwick series

1220 ± 70

HAR-8526. 10743 $\delta^{13}C = -31.8‰$

Wood, AML 872701, from Stanwick, Northamptonshire (52°20′05″N, 00°34′31″W, NGR SP 9707 7175).

Dainton series

2150 ± 80

HAR-8768. D414127 $\delta^{13}C = -25.2‰$

Charcoal, identified as *Prunus avium* and Pomoideae, twigs, ~5 years old, AML 8610323, from the fill of a posthole, which was sealed by stone rubble of a possible ring cairn at 4 km south of Newton Abbot, Devon on summit of Limestone Hill (50°29′21″N, 03°36′41″W, NGR SX 857 668). Collected Aug. 1986 by G. H. Smith; submitted Sept. 1987 by N. D. Balaam.

Comment (N.D.B.): Date will provide a rough *terminus post quem* for construction of the cairn.

650 ± 70

HAR-9018. 40-014B $\delta^{13}C = -27.6‰$

Charcoal, AML 8110601, from Trelan I. Collected June 1981 by G. Smith; submitted Dec. 1982 by N. Balaam.

1340 ± 90

HAR-9163. ABDC823 *Est.* $\delta^{13}C = -21.0‰$

Bone, from Abingdon Drayton cursus; submitted Nov. 1983 by R. Chambers, Oxford Archaeology Unit.

1020 ± 80

HAR-3969. BTS80501 $\delta^{13}C = -22.5‰$

Bone from Bell Tout shaft (50°44′19″N, 00°12′25″E, NGR TV 557 956) Collected May 1980 and submitted July 1980 by O. R. Bedwin, Institute of Archaeology, London.

Jeffs Farm series

4800 ± 70

HAR-4638. TT815 $\delta^{13}C = -25.5‰$

Charcoal, AML 813630, from a small pit or posthole that also contained Neolithic bowl pottery and flints at Jeffs Farm, Tattershall Thorpe, Lincolnshire (53°07′47″N, 00°09′03″, NGR TF 237 608). Collected March 1981 and submitted June 1981 by P. Chowne, North Lincolnshire Archaeology Unit.

Tattershall Thorpe series

Samples from Tattershall Thorpe, Lincolnshire (53°07′16″N, 00°10′20″W, NGR TF 223 598).

1480 ± 100

HAR-5107. TT79123B $\delta^{13}C = -28.0‰$

Wood, AML 822602, from an Iron-Age ring ditch. Collected Feb. 1980 by P. Chowne; submitted July 1982 by M. A. Girling.

2210 ± 70

HAR-8527. TT86204 $\delta^{13}C = -28.9‰$

Wood, AML 872565, from the lower levels of an enclosure ditch. Collected April 1986 and submitted March 1987 by P. Chowne.

HAR-8528. TT8615 **1990 ± 160**
$\delta^{13}C$ = −27.4‰

Wood, AML 872566, same as HAR-8527.

Comment (P.C.): Sample establishes the date of the enclosure.

HAR-8529. TT8622 **6410 ± 70**
$\delta^{13}C$ = −27.7‰

Wood, AML 872564, same as above.

Comment (P.C.): Sample dates construction and use of enclosure.

HAR-8530. TT8615 **1940 ± 80**
$\delta^{13}C$ = −28.0‰

Charcoal, AML 872567, from a hearth. Collected March and submitted April 1986 by P. Chowne.

Comment (P.C.): Result establishes the date of secondary site use and enhances the Tattershall Thorpe sequence.

Bain Valley Project series

HAR-8531. LTO7861 **1530 ± 70**
$\delta^{13}C$ = −26.8‰

Charcoal, AML 872568, from the fill of a Neolithic hearth, associated with pottery and animal bone at Low Toynton, Bain Valley (53° 13′ 23″N 00° 05′ 24″W, NGR TF 275 713). Collected May 1986 and submitted March 1987 by P. Chowne.

Comment (P.C.): I hoped sample would date Neolithic activity in the middle Bain Valley and compare with Tattershall Thorpe dates.

5502 series

HAR-2778. 55020542 **940 ± 80**
$\delta^{13}C$ = −20.8‰

Bone, identified as human skull, AML 781574, from Ipswich, (IAS 5502). Collected 1975 by K. Wade; submitted July 1978 by P. Murphy, Centre of East Anglian Studies.

Roach series

HAR-8646. R2UPEAT **2260 ± 80**
$\delta^{13}C$ = −30.3‰

Peat, AML 865052, from a biogenic deposit at 90–100 cm below the present salt-marsh surface at Bartonhall Creek (51°35′09″N, 00°45′17″E, NGR TQ 9081 9110). Collected Aug. 1986 and submitted Sept. 1986 by P. Murphy.

Comment (P.M.): Dates the biogenic deposit to the first millennium BC, which cannot be confidently correlated with similar, earlier deposits elsewhere on the Essex coast, and may relate to a localized event.

Blackwater series

6670 ± 130

HAR-9643. BCORE553 $\delta^{13}C = -28.6‰$

Peat, AML 886497, from a biogenic deposit of early Flandrian date, at 6.11–6.22 m depth, beneath estuarine clay revealed by contractors borehole 553 at the end of Dengie peninsula, near Othona Roman Fort, Blackwater, Essex (51°44′43″N, 00°55′56″E, NGR TM 024 093). Collected Feb. 1987 by T. J. Wilkinson; submitted Aug. 1988 by P. Murphy.

Comment (P.M.): Dates only the early Flandrian organic sediments available. Pollen analysis will provide information on contemporary vegetation but independent dating is needed.

1900 ± 70

HAR-9644. B28244 $\delta^{13}C = -30.1‰$

Wood, AML 886498, from a wooden hurdle structure exposed on the foreshore, Site 28 (51°43′52″N, 00°45′13″E, NGR TL 9014 0725). Collected July 1988 and submitted Aug. 1988 by P. Murphy.

Comment (P.M.): Previously obtained dates on a wooden structure at this site are mainly Iron Age. This sample is from the best preserved hurdle from the site, and the ^{14}C date shows that it is one of the latest structures.

Stansted series

3810 ± 80

HAR-9239. BRS228 $\delta^{13}C = -30.0‰$

Peat, AML 881268, from the base of a section exposed in contractors excavations through valley floor alluvial sediments at 228–238 cm depth at British Rail Section, Valley of Stansted Brook, Stansted, Essex (51°54′08″N, 00°12′50″E NGR TL 523 250). Collected May 1988 and submitted June 1988 by P. Murphy.

Comment (P.M.): Date provides information on phases of soil erosion/alluviation and on vegetational history in the survey area. ^{14}C dates are necessary in the absence of any artifactual dating evidence.

Chigborough Farm series

2980 ± 80

HAR-10199. 10.88971 $\delta^{13}C = -29.3‰$

Wood from the bottom of a water-logged deposit at the bottom of a Bronze-Age well or watering hole. The context was black organic loam, virtually stone-free and sealed by successive fills of gravelly clays and silts at Goldhanger, near Maldon, Essex (51°44′22″N, 00°43′24″E, NGR TL 880 081). Collected Sept. 1988 by M. Waughman; submitted Dec. 1988 by P. Murphy (Waughman 1989).

Comment: Date is consistent with LBA pottery.

Southacre ring ditch series

HAR-10238. SAC1449 **1150 ± 70**
$\delta^{13}C$ = −21.9‰

Bone, identified as human, from a grave dug immediately outside a ring ditch containing similar graves (52°41′59″N, 00°40′08″E, NGR TF 8032 1472). Collected June 1988 by J. J. Wymer; submitted Dec. 1988 by P. Murphy.

Comment: (P.M.): Date establishes probable association with similar burials in the fills of the ring ditch.

HAR-10239. SAC1305 **1710 ± 90**
$\delta^{13}C$ = −21.8‰

Bone, identified as human, from a grave dug into the fill of a ring ditch (52°41′59″N, 00°40′08″E, NGR TF 8032 1472). Collected May 1988 by J. J. Wymer; submitted Dec. 1988 by P. Murphy.

Comment (P.M.): Result confirms an early Saxon date for these burials, which were otherwise dated only by a few sherds of vaguely associated pottery.

Mount Farm series

HAR-4796. MF101 i **3080 ± 90**
$\delta^{13}C$ = −20.4‰

Bone, identified as animal from Mount Farm, Berinsfield (51°39′59″N, 01°09′20″W, NGR SU 584 968). Collected 1978 and submitted May 1981 by G. H. Lambrick, Oxford Archaeology Unit.

Comment (G.L.): This sample is one of a series of 16 spanning the Middle Neolithic to Late Iron Age. It was from a ring ditch that contained fragments of a MBA bucket urn and surrounded several burial deposits. A bone from one inhumation was dated to 3170 ± 100 BP (HAR-4791), whereas charcoal from a cremation in a small MBA urn yielded an earlier date of 3380 ± 100 BP (HAR-4822). However, the second date may be too early, as it is 1 of 4 charcoal samples in the sequence, of which the other 3 are anomalously early. The ring ditch was stratigraphically earlier than a LBA water hole dated to 3000 ± 90 BP (HAR-4797, -4798). Thus, HAR-4796 entirely agrees with other dates in the sequence on samples of bone and water-logged wood. Very few MBA ring ditches in the upper Thames Valley have been dated; good stratigraphic and artifactual associations of the site make this date a valuable contribution to the chronology of the region.

Claydon Pike series

HAR-5410. FCP 4 **1940 ± 80**
Est. $\delta^{13}C$ = −21.0‰

Bone, from the low levels of an Iron-Age enclosure ditch, which is in the center of the site and belongs to the middle phase (2) of occupation at Claydon Pike, Lechlade, Gloucester. Collected July 1981 by D. Miles, Oxford Archaeology Unit.

Alcester series

1680 ± 70

HAR-8524. 861J $\delta^{13}C = -28.2‰$

Wood, identified as *Alnus glutinosa* Gaertn (alder), AML 872595, from a foundation trench for the late 4th century bastion at Alcester, Warkwickshire. Submitted 1987 by J. Hillam, University of Sheffield.

Comment (J.H.): Wood could not be dendrochronologically dated; thus, ^{14}C dating was required.

Cannington Series

1730 ± 70

HAR-9137. GRAVE 87 $\delta^{13}C = -23.1‰$

Bone, AML 881259, from Cannington, Somerset (51°09′33″N, 03°04′11″W, NGR ST 252 406). Collected 1962/3 by P. A. Rahtz; submitted March 1988 by S. M. Hirst.

Comment (S.M.H.): Date is a rerun for skeleton previously dated by the British Museum (BM-469).

Henley Wood series

1190 ± 90

HAR-8761. GRA 12 $\delta^{13}C = -20.4‰$

Bone, identified as human, from Grave 12, below either Structure 1 or Temple 2 at Henley Wood, Yatton, Avon (51°22′57″N, 02°48′02″W, NGR ST 443 652). Collected ~1974 by E. Greenfield; submitted Sept. 1987 by L. Watts.

3070 ± 90

HAR-9028. MM 220 $\delta^{13}C = -29.1‰$

Peat, AML 790084, from a forested period preceding the first major clearance at Moss Mire, near Barnard Castle, Durham. Collected May 1978 and submitted Jan. 1979 by Mrs. A. M. Donaldson, Department of Archaeology, University of Durham.

Christchurch series

3510 ± 70

HAR-2906. X17-100 $\delta^{13}C = -25.2‰$

Charcoal, identified as oak (*Quercus* sp.) from mature timbers, AML 785392, from a ring ditch. The sample was ~10–15 cm from the base of the ditch in primary silt at Christchurch, Site X17 (50°44′11″N, 01°46′36″W, NGR SZ 1575 9305). Collected Jan./April 1978 and submitted Oct. 1978 by K. Jarvis (Jarvis 1983).

Comment (K.J.): Date confirms the earlier BA date expected for Ring Ditch 1, which was stratigraphically earlier than a LBA settlement. It is also consistent with adjacent Ring Ditch 2, which cut into a pit containing grooved ware, and yielded a sherd from a collared urn.

Staines series

HAR-9023. 50F1423 — **1520 ± 70**; $\delta^{13}C = -25.3‰$

Charcoal, AML 822659, from a large pit 69 cm deep, inside the Neolithic enclosure (Layer 3), Staines, Middlesex. Collected Aug. 1962 by R. Robertson-MacKay; submitted July 1982 by L. Blackmore (AML).

HAR-9024. SEC30B — **3950 ± 70**; $\delta^{13}C = -27.4‰$

Charcoal. Collected Aug. 1962 by R. Robertson-MacKay; submitted Oct. 1988 by L. Blackmore.

HAR-9026. 12F332 — **1380 ± 80**; $\delta^{13}C = -25.6‰$

Charcoal, AML 822660, from a gully inside the Neolithic enclosure. Collected Aug. 1962 by R. Robertson-MacKay; submitted Oct. 1988 by L. Blackmore.

Enderby Iron Age Farmstead series

HAR-9410. A3083C1 — **1870 ± 90**; $\delta^{13}C = -25.0‰$

Charcoal, identified as oak, ash, poplar, field maple, rowan – twigs/fragments, from an eaves drip trench surrounding a first-phase Iron-Age building at Grove Farm, Enderby, Leicestershire (52°35′47″N, 01°11′11″W, NGR SK 551 002). Collected Nov. 1984 and submitted Jan. 1988 by P. Clay, Leicestershire Museums Archaeology Unit.

Comment (P.C.): Sample may derive from the destruction of the building and thus, provides a terminal date for its use.

Stow Church series

HAR-8809. ST83/62 — **960 ± 80**; $\delta^{13}C = -22.0‰$

Bone, identified as a long bone, AML 844227, from Stow Church, Lincolnshire.

HAR-9693. ST83322 — **1640 ± 70**; $\delta^{13}C = -23.6‰$

Bone, identified as cattle, AML 858537, from the earliest level of activity on the site at Stow Church, Lincolnshire. Collected Sept. 1983 by Naomi Field; submitted Nov. 1984 by the Trust for Lincolnshire Archaeology.

Comment (N.F.): Result dates domestic use of the site.

Hayling Island Saxon series

HAR-8535 E46 — **1840 ± 100**; $\delta^{13}C = -25.9‰$

Charcoal, AML 872579, from a late Iron-Age gully forming part of the circular structure of a temple, from Hayling Island, Hampshire (50°49′20″N, 00°58′19″W, NGR SU 724 031). Collected Sept. 1977 and submitted April 1986 by G. Soffe, Air Photographs Unit, Royal Commission for the Historical Monuments of England (RCHM(E)).

Comment (R.S.): Dates construction and use of the Iron-Age temple.

HAR-8537. V57A/2 — **1720 ± 100**; $\delta^{13}C = -26.3‰$

Charcoal, AML 872584, from the base of a mid-Saxon pit dug into a courtyard of the Roman temple. Collected Sept. 1979 by A. King; submitted April 1986 by G. Soffe.

Comment (G.S.): Dates the mid-Saxon occupation of the site.

Baldock Upper Walls Common series

HAR-5964. UWCA2224 — **1990 ± 110**; $\delta^{13}C = -21.0‰$

Bone, AML 840026, from primary silt of major north-south ditch of a large agricultural enclosure at Baldock Upper Walls Common, northeast of Baldock (51°59′24″N, 00°10′46″W, NGR TL 250 340). Collected 1982 by G. R. Burleigh; submitted Sept. 1983 by J. C. Drake, Letchworth Museum.

Comment (G.R.B.): This will be a starting date for a series of intersecting enclosures, and hence, will date the subdivision of the land for agricultural purposes around the late Iron-Age/Roman settlement. It will also help narrow the date range of associated pottery.

Heslerton Parish Project series

HAR-6518. HGP00007C — **1700 ± 80**; $\delta^{13}C = -25.0‰$

Charcoal, AML 841207, from fill of SFB context 2M00217 at Vale of Pickering, Yorkshire (54°10′33″N, 00°35′42″W, NGR SE 917 765); submitted Nov. 1983 by D. J. Powlesland.

Comment (D.P.): Date will be used to compare with burial dates.

Beeston Castle series

HAR-5610. BCOGRC07 — **1890 ± 120**; $\delta^{13}C = -26.4‰$

Charcoal, from Context BCO375A timber, *in situ* in a stone rampart below the foundation level of medieval Beeston Castle, Bunbury, Cheshire (53°07′43″N, 02°41′26″W, NGR SJ 538 593). Submitted June 1983 by P. Hough.

HAR-6461. BCO54200 — **5330 ± 110**; $\delta^{13}C = -27.2‰$

Charcoal, AML 834995. Submitted Aug. 1984 by P. Hough.

Longmoor series

6040 ± 110
HAR-4475. LFMBD4 $\delta^{13}C = -27.1‰$

Wood, identified as oak and birch, from the lower part of a horizon of gley podzol developed on the Folkestone Beds division of the Lower Greensand at Longmoor, Site I, East Hampshire. Collected summer 1979 and submitted April 1981 by Dr. R. M. Jacobi.

Comment (R.M.J.): Mesolithic-type flint artifacts were found in the same part of the profile.

Charlwood series

Samples from Charlwood, Surrey (51°09′31″N, 00°14′14″W, NGR TQ 2325 4145). Collected Dec. 1979 and submitted April 1981 by R. Ellaby (Ellaby 1983, 1987).

4340 ± 100
HAR-4531. PIT 1-1214 $\delta^{13}C = -28.6‰$

Charcoal, AML 820433, at 33 cm depth of PIT 1, excavated 46 cm into Weald clay, and containing Mesolithic flint artifacts and calcined bone at Charlwood Site 1.

5270 ± 90
HAR-4532. PIT 1-1416 $\delta^{13}C = -27.3‰$

Charcoal, AML 820432, at 38 cm depth.

5640 ± 90
HAR-4533. PIT 1-1618 $\delta^{13}C = -26.3‰$

Charcoal, AML 820431, from the basal 43 cm depth.

Avebury series

This series of dates puts Avebury, Wiltshire (51°25′N, 1°51′ W) in the same horizon as other big southern English henges, such as Durrington Walls and Mount Pleasant. A detailed chronology of the site remains open to interpretation. HAR-10325, -10500 and -10063 date material on the old land surface under the bank of the henge. HAR-10502 dates the primary ditch fill, and -10064, the secondary fill. At face value, -10502 is slightly earlier than Durrington Walls and Mount Pleasant. HAR-10326 dates a possible extension to the bank, compatibly with -10502, but hardly later than -10500, from the old land surface. HAR-9696, -10061, -10062 and -10327 are from stone holes of the main stone circle. HAR-9696 and -10061 must be rejected as intrusive; -10327, on bone, and perhaps more reliable than -10062 on charcoal, might suggest construction later than the ditch and bank. HAR-9694, -9695 and -10501 are from the occupation area of the West Kennet Avenue. HAR-9694 must be rejected; -9695 and -10501 agree with finds from the occupation, but neither dates the erection of stones in the Avenue (Gray 1935; Smith 1965; Evans, Pitts & Williams 1985).

4260 ± 80
HAR-9695. SQUARE 3 $\delta^{13}C = -26.7‰$

Charcoal from Hole 4 in the occupation area on the West Kennet Avenue. Collected 1934 by A. Keiller; submitted Sept. 1987 by M. Pitts, Avebury Museum.

HAR-10061. 831785 **2430 ± 70** $\delta^{13}C = -25.8‰$

Charcoal, AML 831785, from a stake hole on the edge of Stonehole 8 of the main stone circle in the southwest quadrant. Collected 1938 by A. Keiller; submitted Sept. 1987 by M. Pitts.

HAR-10062. 831784 **4130 ± 90** $\delta^{13}C = -27.5‰$

Charcoal, AML 831784, from the bottom of Stonehole 41 in the main stone circle in the northwest quadrant. Collected 1937 by A. Keiller; submitted Sept. 1987 by M. Pitts.

HAR-10063. 822624 **4380 ± 80** $\delta^{13}C = -26.7‰$

Charcoal, AML 822624, from the old land surface under the henge bank in the southeast quadrant (Cutting X). Collected 1914 by H. St. G. Gray; submitted Sept. 1987 by M. Pitts.

HAR-10064. 822623 **3690 ± 80** $\delta^{13}C = -25.4‰$

Charcoal, AML 822623, from a deposit of burned material beneath a 'dwarf' burial in the secondary fill of the ditch (*ca.* 2 m below modern surface) in the terminal of the ditch east of the south entrance (Cutting IX). Collected 1914 by H. St. G. Gray; submitted 1984 by M. Pitts.

HAR-10325. GBA82+63 **4640 ± 70** $\delta^{13}C = -24.8‰$

Bone, AML 831778, from the old land surface under a bank of henge in the northwest quadrant (Cutting II). Collected 1982 and submitted June 1985 by M. Pitts.

HAR-10326. 831779 **4160 ± 90** $\delta^{13}C = -24.5‰$

Antler, AML 831779, from the above bank of the henge in the northwest quadrant, above a possible revetment trench. Collected 1937 by A. Keiller; submitted June 1985 by M. Pitts.

HAR-10501. 831787 **4280 ± 100** $\delta^{13}C = -24.3‰$

Bone, identified as antler, AML 831787, from a pit in the occupation area on the West Kennet Avenue. Collected 1934 by A. Keiller.

HAR-10502. 831780 **4300 ± 90** $\delta^{13}C = -23.9‰$

Bone, identified as antler pick, AML 831780, from the primary fill of the henge ditch west of the south entrance (Cutting I). Collected 1909 by H. St. G. Gray; submitted June 1985 by M. Pitts.

HAR-9694. SQUARE 2 **5780 ± 80** $\delta^{13}C = -27.3‰$

Charcoal from Posthole 1 in the occupation area on the West Kennet Avenue. Collected 1934 by A. Keiller; submitted 1987 by M. Pitts.

HAR-10500. AV2 **4190 ± 90**
$\delta^{13}C = -26.2‰$

Charcoal, AML 831777, identified as *Crataegus* sp., *Aesculus* sp. and *Corylus*, from the old land surface under the henge bank. Collected 1938 by A. Keiller; submitted June 1985 by M. Pitts.

HAR-10327. 831783 **3870 ± 90**
$\delta^{13}C = -21.5‰$

Bone, identified as pig, from the bottom of Stonehole 44 of the main stone circle in the northwest quadrant. Collected 1937 by A. Keiller; submitted June 1985 by M. Pitts.

HAR-9696. CIRCLE 10 **2080 ± 110**
$\delta^{13}C = -28.2‰$

Charcoal from an ash layer in Stonehole 44, of the main stone circle in the northwest quadrant. Collected 1937 by A. Keiller; submitted Sept. 1987 by M. Pitts.

Ewanrigg series

HAR-5962. EWR83114 **1620 ± 150**
$\delta^{13}C = -25.9‰$

Bone, AML 840107, from Context 14, a stone-lined cist containing a smashed collared urn at Ewanrigg, Maryport, Cumbria (54°42′05″N, 03°29′56″W, NGR NY 0342 3508). Collected Oct. 1983 by R. Bewley (RCHM(E)).

HAR-7073. EWR85072 **1070 ± 70**
$\delta^{13}C = -27.0‰$

Charcoal, AML 858544, from Context 72, a tunnel-like 'entrance' to a corn-drying kiln (54°42′05″N, 03°29′56″W, NGR NY 0342 3508). Collected Aug. 1985 and submitted Oct. 1985 by R. H. Bewley.

Comment (R.B.): Result establishes contemporaneity between tunnel and chamber.

HAR-7076. EWR85068 **810 ± 80**
$\delta^{13}C = -24.6‰$

Charcoal, AML 858547, from probable stake holes, part of a corn-drying kiln. Collected Aug. 1985 and submitted Oct. 1985 by R. H. Bewley.

Comment (R.B.): Dates the final use of the corn-drying kiln.

HAR-9459. EWR87346 **1450 ± 80**
$\delta^{13}C = -27.9‰$

Charcoal, AML 880750 (54°41′46″N, 03°29′51″W, NGR NY 035 345). Collected Aug. 1987 and submitted Feb. 1988 by R. H. Bewley.

Comment (R.B.): Dates the earliest context on the settlement.

HAR-9460. EWR87349 **2970 ± 60**
$\delta^{13}C = -25.9‰$

Charcoal, AML 880751, from a burned layer within (346), the earliest feature of the site, possibly a storage pit (NGR NY 035 352). Collected Aug. 1987 and submitted Feb. 1988 by R. H. Bewley.

Maryport series

4440 ± 70

HAR-8788. EWR86084 $\delta^{13}C = -28.6‰$

Charcoal, AML 8650270, from an oval pit with many stones, a beaker and a stone-lined bottom, a layer of quartz pebbles, at 1 m south of Maryport, Cumbria (54°42′02″N, 03°29′51″W, NGR NY 035 350). Collected Aug. 1986 and submitted Oct. 1986 by R. Bewley.

Comment (R.B.): The discovery of this beaker pit is unexpected and important in terms of the relationship between the Bronze Age and Beaker period in the length of use of the site as a cemetery. The disturbance to the pit suggests that this date cannot be taken too seriously.

Amesbury series

3290 ± 80

HAR-10514. NEWB49 $\delta^{13}C = -24.7‰$

Charcoal, from a cremation pit at New Barn B3, Amesbury, Wiltshire (51°10′29″N, 01°47′33″N, NGR SU 145 418). Submitted Feb. 1990 by D. Jordan, AML.

3610 ± 90

HAR-10515. NEWB8 $\delta^{13}C = -25.8‰$

Charcoal, from the middle ditch at New Barn B4. Submitted Feb. 1990 by D. Jordan.

4070 ± 90

HAR-10516. NEWB10 $\delta^{13}C = -24.6‰$

Charcoal, from the filling of a horseshoe pit at New Barn B4. Submitted Feb. 1990 by D. Jordan.

Haddenham series

Samples from Haddenham, Upper Delphs Terrace, Cambridgeshire (52°20′21″N, 00°04′17″E, NGR TL 411 733).

3620 ± 110

HAR-8094. HAD84 IV $\delta^{13}C = -25.0‰$

Charcoal. Submitted July 1985 by I. Hodder, Department of Archaeology, University of Cambridge.

4960 ± 90

HAR-9172. HAD6LB17 $\delta^{13}C = -26.4‰$

Wood. Submitted March 1988 by I. Hodder.

4490 ± 140

HAR-10512. HAD87CE $\delta^{13}C = -25.2‰$

Peat.

HAR-10513. HAD IX 87 **2110 ± 90**
$\delta^{13}C = -28.0‰$

Wood. Submitted July 1988 by C. Evans, Department of Archaeology, University of Cambridge.

HAR-10518. 3911 **4020 ± 110**
$\delta^{13}C = -26.8‰$

Charcoal, AML 886481, from the fill of a small pit in the middle of a causewayed enclosure. Collected Oct. 1987 and submitted July 1988 by C. Evans.

Comment (C.E.): The pit was just outside of the HAD VII enclosure and contained domestic rubbish, including worked flint and plainware bowls. Results date this important assemblage and place it in the chronology of the site.

HAR-10519. 3806 **2240 ± 80**
$\delta^{13}C = -27.4‰$

Wood, AML 886482, from the primary fill of the north ditch of the south-lying enclosure, sealed by an upcast bank of the north enclosure.

Comment (C.E.): Dates the south-lying enclosure.

HAR-10520. 0362 **4690 ± 90**
$\delta^{13}C = -24.7‰$

Charcoal, AML 886477, from a burned post in secondary fills of the butt of a causewayed enclosure ditch. Collected Sept. 1982 by I. Hodder and C. Evans; submitted July 1988 by C. Evans.

Comment (CE): Dates the later phase of activity/usage on the east side of the enclosure.

Brean Down series

HAR-9153. BD 1352 **3100 ± 100**
$\delta^{13}C = -22.8‰$

Material from Unit 16, part of Unit 4, the latest of the Bronze-Age occupation horizons at Brean Down, Sandcliffe, at Brean, near Burnham on Sea, Somerset (NGR 2957 5872). Collected 1985 and submitted Nov. 1987 by M. Bell, Archaeology Unit, St. David's College (Bell 1986, 1990).

Comment (M.G.B.): This and another date (3400 ± 90, HAR-9155) from Unit 4 are earlier than the dates suggest, based on the gold bracelets from this unit (~3000–2600 BC), or the estimated pottery date in the first quarter of the third millennium BP. Another date for Unit 4 (2730 ± 70, HAR-9151) agrees well with the artifactual evidence.

Low Hauxley-B series

Fine detrital lacustrine mud from a ~60-cm-thick organic sequence overlying freshwater silts, exposed in a sea-cliff, ~70 cm, of a multicomponent (Mesolithic, Bronze Age) archaeological site (Bonsall 1984) near Low Hauxley, 4 km south of Amble, Northumberland (55°18′34″N, 01° 33′09″W, NGR NU 284 018), ~270 m south of Low Hauxley (Innes & Frank 1988; Bonsall 1984). Samples were collected from a cleaned cliff exposure in Sept. 1986 by R. Tipping, Department of Archaeology, Edinburgh University, stored at 4°C, and submitted Feb. 1987.

HAR-8977. LHB-5 60–58 cm **4280 ± 100** $\delta^{13}C = -30.6‰$

Fine detrital mud.

HAR-8976. LHB-4 56–54 cm **4700 ± 70** $\delta^{13}C = -29.5‰$

Fine detrital mud with occasional roots, possibly not contemporaneous.

HAR-8975. LHB-3 50–46 cm **3360 ± 70** $\delta^{13}C = -29.5‰$

Fine detrital mud.

HAR-8974. LHB-2 39–37 cm **3280 ± 60** $\delta^{13}C = -29.4‰$

Fine detrital mud with occasional roots.

HAR-8973. LHB1 **2330 ± 60** $\delta^{13}C = -30.3‰$

Fine detrital mud.

General Comment (RT): The series relates to a detailed pollen profile of the sediments. With one exception, the series agrees in age with the pollen spectra, post-elm decline, and with two ^{14}C dates from closely comparable sediment and pollen stratigraphy at Low Hauxley. (Innes & Frank 1988).

HAR-8977 dates the change from fluviatile sedimentation to ponding, tentatively related to a small rise in sea level. The date is significantly younger (at 2 σ) than overlying HAR-8976. Internal evidence does not resolve this 'date reversal', but peat developed at Low Hauxley (Innes & Frank 1988) at 4720 ± 50 (SRR-1421); whether this implies HAR-8977 to be 'too young' is unclear.

The beginning of a phase of lowered pond level is dated by HAR-8976, and the resumption of raised water levels by HAR-8975; a small oscillation in sea level in inducing this change is suspected, but is difficult to demonstrate. A reduction in willow around the pond is dated to ~3280 (HAR-8974), suggesting an increase in agricultural activity. The covering of the pond by an advancing sand sheet is dated by HAR-8973; the comparable date at Low Hauxley is 2810 ± 40 (SRR-1420).

South West Fen Dyke Survey series

HAR-8510. SWFC1 **3740 ± 100** $\delta^{13}C = -28.1‰$

Peat from upper buried soil, from Crowtree Farm, Cambridgeshire (52°51′04″N, 00°15′34″E, NGR TF 5213 3061). Submitted April 1987 by C. French, Fenland Archaeology Trust (French & Pryor, in press).

HAR-8913. SWFC4A **3190 ± 90** $\delta^{13}C = -28.1‰$

Charcoal from the base of a lower peat trench. Submitted March 1987 by C. French.

HAR-8513. SWFC4 **3660 ± 60**
$\delta^{13}C = -27.6‰$

Peat from a thin exposure of basal peat overlying the buried soil and sealed by fen clay. Submitted March 1987 by C. French.

HAR-8511. SWFC2 **2800 ± 100**
$\delta^{13}C = -27.3‰$

Charcoal from a feature at Northey "Island," Cambridgeshire (52°50′49″N, 00°06′48″E, NGR TF 4230 2983). Submitted March 1987 by C. French.

HAR-8912. SWFC3 **2090 ± 80**
$\delta^{13}C = -26.7‰$

Charcoal from a sealed plowsoil/occupation horizon, Borough Fen Site 7, underlying alluvium (52°38′34″N, 00°14′44″E, NGR TF 5192 0740). Submitted March 1987 by C. French.

Hayes Farm series

HAR-8674. HFCH030 **8140 ± 160**
$\delta^{13}C = -25.0‰$

Charcoal from Hayes Farm, Clyst Honiton, East Devon (50°44′23″N, 03°25′46″W, NGR SX 9915 9438). Collected 1987 and submitted July 1987 by T. Pearson, Exeter City Museum.

HAR-8676. HFCH066 **1910 ± 100**
$\delta^{13}C = -27.2‰$

Collected 1987 and submitted July 1987 by T. Pearson.

Comment (T.P.): These samples were obtained during an excavation of aerial crop marks. The result supplements very few ^{14}C dates currently available for Barrows/Ring ditches in southwest England.

Sutton Common series

HAR-8916. SC022CO2 **2240 ± 90**
$\delta^{13}C = -30.7‰$

Peat, AML 881215, from the top peat layer underlying the tail of the bank (opposite to the ditch) at Sutton Common, Norton parish, Doncaster, South Yorkshire (53°36′08″N, 01°08′57″W, NGR SE 563 121). Collected Nov. 1987 and submitted Dec. 1987 by B. Sydes, South Yorkshire Archaeology Unit.

Comment (B.S.): Dates the *terminus ante quem* for the construction of the bank.

Hob Ditch 1987 series

HAR-8874. 32/8/1 **2530 ± 90**
$\delta^{13}C = -27.3‰$

Soil, AML 878267, from the smaller of two ditches at the second lowest fill of recut, one of several layers that accumulated rapidly after the recutting at Lapworth, Warwickshire (52°19′50″N, 01°45′04″W, NGR SP 1695 7036). Collected Aug. 1987 and submitted Oct. 1987 by S. Cracknell.

Comment (S.C.): Result establishes the earthwork as pre-Roman.

Jubilee Hall series

950 ± 60
HAR-9134. 003/107 $\delta^{13}C = -23.3‰$

Bone, AML 881225, from the fill of a pit cutting through a sequence of layers, which, in turn, seal a grave. Stratigraphically, this is the latest feature at Covent Garden, London WC2 (51° 30′40″N, 00°07′14″W, NGR TQ 3040 8085). Collected May 1985 by R. Whytehead; submitted Oct. 1987 by R. Whytehead and L. Blackmore, Museum of London.

Comment (L.B.): Dates the back-filling of the feature and provides a date range for the accumulation of urban deposit above the grave. The result provides a guide to dating the phasing of the site and complements pottery-dating evidence for the mid-Saxon period.

Glastonbury series

Wood samples from a series of late-Saxon features at Glastonbury, Somerset (51°08′43″N, 02°43′09″W, NGR ST 4970 3875). Other ^{14}C dates from this series are HAR-7044 and -7045 (Walker, Williams & Otlet 1990) from the 10th century monastic enclosure ditch.

1120 ± 80
HAR-9207. GCF87/09 $\delta^{13}C = -30.7‰$

Wood, from a clay bank in Trench C. The sample is from sharpened revetment stake from the bank of a watercourse. Collected July 1987 and submitted March 1988 by C. and N. Hollinrake (1991).

Comment (C.H. and N.H.): Dates the construction of this feature.

1340 ± 100
HAR-9208. GCF87/12 $\delta^{13}C = -32.8‰$

Wood, from GFF 87 Trench BB, Ditch D (51°08′40″N, 02°43′11″W, NGR ST 4965 3865). The sample is from a sharpened stake from primary fill of a ditch sealed by the bank of the same watercourse, above. Collected July 1987 and submitted March 1988 by C. and N. Hollinrake (1991).

Comment (C.H. and N.H.): provides a suitable *terminus post quem* for this watercourse.

Raunds Area Project: River Nene Palaeochannels series

4300 ± 150
HAR-9241. RAC1 $\delta^{13}C = -31.6‰$

Peat, AML 881262, from a monolith from a small exposed section through a paleochannel at Nene floodplain, near Raunds, Northantshire (52°20′39″N, 00°34′07″W, NGR SP 975 728). Collected June 1987 by A. G. Brown and M. Keough; submitted June 1988 by A. G. Brown, Department of Geography, University of Leicester.

Comment (A.G.B.): Dates paleochannel abandonment and provides a basal age for the pollen profile.

HAR-9242. RAPD1 **1970 ± 80**
$\delta^{13}C = -29.9‰$

Peat, identified as sediment type and pollen and plant macrofossil, AML 881263, from Trench B139, cut across a paleochannel (52°20′23″N, 00°34′39″W, NGR SP 973 724). Collected Oct. 1987 and submitted June 1988 by A. G. Brown.

Comment (A.G.B.): Result should provide a reliable *post terminum* date of paleochannel abandonment.

HAR-9243. RAPE1 **9370 ± 170**
$\delta^{13}C = -31.6‰$

Peat, AML 881264, from the basal 5 cm of a monolith from Trench B4141 across a paleochannel (NGR SP 969 723). Collected Oct. 1987 by A. G. Brown and M. Keough; submitted June 1988 by A. G. Brown.

Comment (A.G.B.): Dates abandonment of the paleochannel and provides a basal age for the pollen profile.

Cripps River series

HAR-9188. CRO-1 **2900 ± 90**
$\delta^{13}C = -28.2‰$

Peat, AML 878292, from the base of peat overlying clay, Feature 13, containing briquetage, Trench A, at Cripps River, East Huntspill, Somerset (51°11′25″N, 02°54′11″W, NGR ST 369 439). Collected Oct. 1986 by R. McDonnell, V. Straker and A. Caseldine; submitted Sept. 1987 by R. McDonnell, Somerset County Council (McDonnell 1985, 1986).

Comment (R.M.): Dates salt production activity in an area of peat deposition.

Lower Great Moor series

HAR-9145. X4802512 **1560 ± 60**
$\delta^{13}C = -30.6‰$

Peat, AML 881221, at 1.05 m depth, overlying organic silty clay and fine gravel at Lower Great Moor, Tithe 1422, on the floodplain of River Wolf, a raised area on river gravels (50°42′09″N, 04°13′42″W, NGR SX 4266 9165). Collected Jan. 1988 by T. Pearson and V. Straker; submitted Jan. 1988 by V. Straker, Exeter City Museum.

Comment (C.H.): Archaeological excavations and pollen analysis of the Wolf Valley are underway, before the area is flooded by the Roadford reservoir.

References

Bell, M. 1986 Brean Down. *Current Archaeology* 102: 218–221.

_____1990 Brean Down excavation 1983–1987. *English Heritage Archaeological Reports* 15(9): 107–113.

Bonsall, C. 1984 Low Hauxley, Northumberland. *Proceedings of the Prehistory Society* 50: 398.

Butterworth, C. A. and Lobb S. J., in press, Excavations in the Burghfield area, Berkshire. Developments in the Bronze Age and Saxon landscapes. *Wessex Archaeology.*

Dent, J. S. 1983 A summary of the excavations carried out in Garton and Wetwang Slack 1964–80. *East Riding Archaeologist* 7 (Appendix A): 1–12.

Drewett, P. 1975. The excavation of an oval burial mound of the third millennium bc at Alfriston, East Sussex, 1974. *Proceedings of the Prehistoric Society* 41: 119–152.

_____1982, The archaeology of Bullock Down, Eastbourne, East Sussex. The development of a landscape. *Sussex Archaeological Society Monograph* I, Lewes.

Ellaby, R. L. 1983 Charlwood: Mesolithic site. *Surrey Archaeological Society Bulletin* 182.

_____1987 The upper Palaeolithic and Mesolithic in Surrey. *In* Bird, J. and Bird, D. G., eds., *The Archaeology of Surrey to 1540*: 53–70.

Evans, J. G., Pitts, M. W. and Williams, D. 1985 An excavation at Avebury, Wiltshire, 1982. *Proceedings of the Prehistoric Society* 51: 305–310.

French, C. A. I. and Pryor F. M. M., in press, The Southwest Fen Dyke Survey Project 1982–86. *East Anglian Archaeology.*

Gingell, C. and Lawson, A. J. 1984 The Potterne project – Excavation and research at a major settlement of the late Bronze Age. *Wiltshire Archaeological and Natural History Magazine* 78: 31–34.

_____1985 Excavations at Potterne 1984. *Wiltshire Archaeological and Natural History Magazine* 79: 101–108.

Gray, H. St. G. 1935 The Avebury excavations 1908–1922. *Archaeologia* 84: 99–162.

Green, C. and Rollo-Smith, S. 1984 The excavation of eighteen round barrows near Shrewton, Wiltshire. *Proceedings of the Prehistory Society* 50: 255–318.

Green, C. J. S. 1987 Excavations at Poundbury, Dorchester, Dorset, 1966–1982, Vol. 1: The settlement. *Dorset Natural History Archaeology Society Monograph* 7.

Heighway C. M. 1978 Excavations at Gloucester; St. Oswald's Priory 1975–6. *Antiquaries Journal* 58: 103–82.

_____1980 Excavations at Gloucester, 5th Interim Report, St. Oswald's Priory 1977–8. *Antiquaries Journal* 60: 207–26.

Hollinrake, C. and Hollinrake, N. 1991 A late Saxon monastic enclosure ditch and canal, Glastonbury, Somerset. *Antiquity* 65(246): 117–118.

Innes, J. B. and Frank, R. M. 1988 Palynological evidence for Late Flandrian coastal changes at Druridge Bay, Northumberland. *Scottish Geographical Magazine* 104: 14–23.

Jarvis, K. S. 1983 Excavations in Christchurch 1969–1980. *Dorset Natural History and Archaeology Society Monograph* 5: 134–136.

McDonnell, R. 1985 *Archaeological Survey of the Somerset claylands. Report on survey work 1984–85.* Somerset County Council.

_____1986 *Archaeological Survey of the Somerset claylands. Report on survey work 1985–86.* Somerset County Council.

Otlet, R. L. 1979 An assessment of errors in liquid scintillation methods of radiocarbon dating. *In* Berger, R. and Suess, H. E., eds., *Radiocarbon Dating*. Proceeding of the 9th International ^{14}C Conference. Berkeley, University of California Press: 256–267.

Rahtz, P. and ApSimon, A. M. 1962 Excavations at Shearplace Hill, Sydling St. Nicholas, Dorset, England. *Proceedings of the Prehistory Society* 28: 289–328.

Smith, I. 1965 *Windmill Hill and Avebury.* Oxford, Clarendon Press.

Stuiver, M. and Reimer, P. J. 1986 A Computer Program for Radiocarbon Age Calibration.*In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2B): 1022–1029.

Walker, A. J., Williams, N. and Otlet, R. L. 1990 Harwell radiocarbon measurements VIII. *Radiocarbon* 32(2): 165–196.

Waughman, M. 1989 Chigborough Farm, Goldhanger; The first season's excavation of an early settlement. *Essex Journal* 24: 15–18.

Wickenden, N. P. 1986 Prehistoric settlement and the Romano-British settlement at Heybridge, Essex. *Essex Archaeology and History* 17: 7–68.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 71–82]

INSTITUT ROYAL DU PATRIMOINE ARTISTIQUE RADIOCARBON DATES XIV

MICHELE DAUCHOT-DEHON and MARK VAN STRYDONCK

Royal Institute of Cultural Heritage, B-1040 Brussels, Belgium

This list contains the results of ^{14}C determinations that we obtained in 1988 and 1989. $\delta^{13}C$ was measured by the Free University, Brussels. Our dating techniques have been described previously (Dauchot-Dehon & Heylen 1971; Dauchot-Dehon, Van Strydonck & Heylen 1986).

GEOLOGICAL SAMPLES

BELGIUM

Western coastal plain of Belgium series

The following results complete the previously published series (Dauchot-Dehon & Van Strydonck 1989) of peat from west Vlaanderen. Collected by L. Denys and submitted 1988 by C. Baeteman, Geological Service of Belgium (Baeteman 1989).

1180 ± 40

IRPA-826. Spoorweg 2.61 — *$\delta^{13}C$ = −25.1‰*

Peat from the top of the upper layer, 2.61–2.68 m below surface, at Lampernisse (51°03′N, 2°47′E).

5850 ± 50

IRPA-834. Spoorweg 6.09 — *$\delta^{13}C$ = −26.6‰*

Peat from the top of an intercalated layer, 6.09–6.15 m below surface, at Lampernisse.

4920 ± 50

IRPA-848. Spoorweg 3.38 — *$\delta^{13}C$ = −26.1‰*

Peat from the base of the upper layer, 3.38–3.45 m below surface, at Lampernisse.

6370 ± 60

IRPA-871. Spoorweg 6.45 — *$\delta^{13}C$ = −25.5‰*

Peat from the base of the second layer, 6.45–6.50 m below surface, at Lampernisse.

6670 ± 60

IRPA-927. Spoorweg 7.61 — *$\delta^{13}C$ = −26.5‰*

Peat from the top of the base layer, 7.61–7.70 m below surface, at Lampernisse.

4240 ± 60

IRPA-831. Orthodoxe kerk 6.95 — *$\delta^{13}C$ = −27.4‰*

Peat from the base of an intercalated layer, 6.95–7.00 m below surface, at Pervijze (51°03′20″N, 2°47′32″E).

IRPA-832. Orthodoxe kerk 2.52 **2690 ± 40**
$\delta^{13}C = -29.8‰$

Peat from the top of the upper layer, 2.52–2.57 m below surface, at Pervijze.

IRPA-833. Orthodoxe kerk 2.93 **3740 ± 40**
$\delta^{13}C = -28.0‰$

Peat from claying level in the upper layer, 2.93–2.98 m below surface, at Pervijze.

IRPA-847. Orthodoxe kerk 1.61 **2230 ± 40**
$\delta^{13}C = -27.3‰$

Peat from the top of the upper layer, 1.61–1.68 m below surface, at Pervijze.

IRPA-846. Westende 3.90 **5120 ± 50**
$\delta^{13}C = -26.5‰$

Peat from the base of the upper layer, 3.90–3.95 m below surface, at Westende (51°09′53″N, 2°46′47″E).

IRPA-849. Vliegveld 5.59 **5960 ± 60**
$\delta^{13}C = -27.1‰$

Peat from the second layer, 5.59–5.65 m below surface, at Leffinge (51°10′N, 2°53″E).

IRPA-924. Vliegveld 5.17 **5540 ± 50**
$\delta^{13}C = -27.6‰$

Peat from the base of the upper layer, 5.17–5.22 m below surface, at Leffinge.

General Comment (C.B.): Dates from the western coastal plain can be grouped into three series:

1. *Basal peat*
   IRPA-927 – the base of the peat shows an age gradient in relation to the depth of the Pleistocene subsurface and the Holocene sea-level curve.
   IRPA-871 – the top of the basal peat represents the time when the area became influenced by marine and/or coastal sedimentation.
2. *Second regional peat layer*
   IRPA-831 – base; IRPA-834 – top; IRPA-849 – mean; the ages are concordant with each other as well as with previous dates (IRPA-612, Dauchot-Dehon & Van Strydonck 1987: 197).
3. *First regional peat layer or surface peat*
   IRPA-833 dates a marine intercalation in the surface peat. From previous dates, this intercalation shows a rather regional significance (IRPA-860, -727 and -527 in, respectively, Dauchot-Dehon & Van Strydonck 1989: 189, 1987: 199; Dauchot-Dehon, Van Strydonck & Heylen 1984: 386).

   Top of peatlayer
   IRPA-826, -832 and -847 – peat growth generally ended between 2700 and 2200 BP, and in more landward areas, between 1900 and 1600 BP. IRPA-826 forms a striking exception; the date is probably too young because of modern rootlet contamination. IRPA-832 and -847 were taken from two different boreholes at a distance of only a few meters. Most probably, the top of the peat (IRPA-832) was partly eroded, although it was not apparent.

Base of peat layer

IRPA-846, -848 and -924 – the results agree with expected dates, as the greatest number of samples from the base of the surface peat date between 4700 and 5220 BP.

Noordzee series

Shells from the North Sea, collected March 1988 by K. de Vos and submitted April 1988 by C. Baeteman. The sample was not big enough to pretreat with 1% HCl; it was cleaned with distilled H_2O and scraped with a scalpel.

IRPA-896. TB333/400C — **1670 ± 80**, $\delta^{13}C = +1.1‰$

Crystal structure determined by an X-ray: 100% aragonite. Diluted; 50.21% sample.

IRPA-897. TB333/400A — **6740 ± 100**, $\delta^{13}C = +0.1‰$

Crystal structure determined by an X-ray: 100% aragonite. Diluted; 54.37% sample.

IRPA-898. TB326/280 — **4870 ± 70**

Crystal structure determined by an X-ray: 100% aragonite. $\delta^{13}C = -2.04‰$

IRPA-899. TB409/100 — **6840 ± 80**, $\delta^{13}C = -0.7‰$

Crystal structure determined by an X-ray: 100% aragonite. Diluted; 87.92% sample.

IRPA-900. TB409/165 — **6940 ± 100**, $\delta^{13}C = -0.9‰$

Crystal structure determined by an X-ray: 90% aragonite, 10% calcite. Diluted; 56.50% sample.

General Comment (C.B.): Samples from *Cardium edule* shells and *Spisula elliptica* (IRPA-896) were taken from vibrocores drilled to determine the age of boundaries of the assumed subdivision, and hence, to establish a chronology of the Holocene deposits. No ^{14}C datings were carried out previously on these deposits, hence, no comparison can be made. However, according to the stratigraphical correlation of the boreholes, one must presume that the post-mortem effect of the shells is rather significant, and the age can only be regarded as maximum.

Schelde series

These samples complete the study of the Schelde River alluvial deposit (Dauchot-Dehon & Van Strydonck 1987: 202; Dauchot-Dehon & Van Strydonck 1989: 187–188) from Temse, Antwerpen (51°06′50″N, 4°11′28″E). Collected and submitted 1988 by P. Kiden, University of Gent, Belgium.

IRPA-911. Tielrodebroek 1 — **4220 ± 50**

Clayey peat from 2.65–2.78 m below surface. $\delta^{13}C = -28.8‰$

IRPA-912. Tielrodebroek 2 — **5070 ± 50**

Clayey peat from 2.98–3.16 m below surface. $\delta^{13}C = -28.0‰$

General Comment (P.K.): IRPA-911 and-912 date, respectively, top and base of a locally occurring organic clay layer, intercalated in the wood peat sequence of the lower Schelde alluvial plain. The large age difference between base and top of the clay layer, in comparison to its thickness (only 40 cm), probably points to strong compaction of the organic clay during and after deposition, which is also comfirmed by lithostratigraphical cross-sections of the alluvial plain at the sampling point.

IRPA-895. Assebroek — **25,340 ± 570** — $\delta^{13}C = -28.8‰$

Peat from Assebroek, Oost Vlaanderen (51°11′N, 03°17′E). Collected and submitted 1988 by C. Verbruggen, University of Gent, Belgium.

Walem Eekhoven series

Organic material from a pleniglacial to Holocene stratigraphic sequence at Duffel, Antwerpen (51°04′30″N, 4°28′E). Collected Oct. 1988 and submitted Dec. 1988 by L. Huysmans, University of Antwerpen, Belgium.

IRPA-929. Duffel 1 — **23,210 ± 310**

1.85 m below surface. — $\delta^{13}C = -28.1‰$

IRPA-965. Duffel 2 — **22,780 ± 420**

2.65 m below surface. — $\delta^{13}C = -27.6‰$

General Comment (L.H.): The Walem samples are from organogeneous layers, 3 and 5 cm thick, consisting of coarse plant remains, macroscopic twiglets and leaves, intercalated between fluvial and loamy sands of the infill of the Flemish valley. The samples were 165 and 85 cm above the Boom clay. Pollen and plant macrofossil analysis indicated tundra-type vegetation.

NORWAY

Svalbard series

Peat from Svalbard, Norway (78°05′N, 21°00′E) collected Aug. 1987 and submitted March 1989 by L. Beyens, University of Antwerpen, Belgium. The samples were used to study the palaeoecology of diatoms and testate amoebae (Beyens & Chardez 1987). Dates from the same valley are GrN-13,349: 3810 ± 40 BP and GrN-13,350: 4995 ± 45 BP.

IRPA-928. Sample 1 RN III — **5580 ± 100**

Peat, 0–3 cm below surface. Diluted; 31.26% sample. — $\delta^{13}C = -25.7‰$

IRPA-991. Sample 2 RN III — **5430 ± 95**

Peat, 14–18 cm below surface. Diluted; 49.93% sample. — $\delta^{13}C = -25.7‰$

IRPA-992. Sample 3 RN III — **5570 ± 65**

Peat, 22–27 cm below surface. Diluted; 56.23% sample. — $\delta^{13}C = -24.9‰$

IRPA-993. Sample 4 RN III — **5645 ± 95**

Peat, 46–50 cm below surface. Diluted; 49.93% sample. — $\delta^{13}C = -25.7‰$

IRPA-994. Sample 5 RN IV **7920 ± 65**

Peat, 0–3 cm below surface. $\delta^{13}C = -24.4‰$

IRPA-837. Sample 6 RN IV **7710 ± 60**

Peat, 33–36 cm below surface. $\delta^{13}C = -26.2‰$

IRPA-838. Sample 7 RN IV **7920 ± 80**

Peat, 56–59 cm below surface. $\delta^{13}C = -24.2‰$

IRPA-995. Sample 8 RN IV **10,980 ± 145**

Peat, 84–88 cm below surface. $\delta^{13}C = -27.5‰$

General Comment (L.B.): The ^{14}C series indicates a disturbed environment; probably the peat layers were exposed to erosion by the river. However, the preliminary results of the rhizopod analysis show some biostratigraphical zonation, related to the hydrological conditions at the bog surface. Interesting is the result of IRPA-995. It confirms the existence of ice-free areas where moss vegetation could exist as early as ~11,000 BP.

BANGLADESH

Dakha series

Samples from Dhaka, Bangladesh (23°45′N, 90°24′E) collected March 1987 by M. D. Hussain Monsur and submitted by C. Baeteman.

IRPA-977. P1 **4040 ± 80**

Wood found in greenish silty clay, Layer 4 in Gulshan Lake. $\delta^{13}C = -28.0‰$

IRPA-978. P4 **4910 ± 70**

Wood found in peaty mud under P1. $\delta^{13}C = -28.9‰$

IRPA-979. P5 **5730 ± 60**

Wood taken from Gulshan Lake in the lower sandy Layer 2. $\delta^{13}C = -27.4‰$

IRPA-980. P7 **8940 ± 100**

Wood found in a gravelly bed under P5. $\delta^{13}C = -27.0‰$

IRPA-981. P8 **4830 ± 70** $\delta^{13}C = -29‰$

Wood found in the top clay layer, below the soil horizon, in the eastern part of Dhaka city.

IRPA-982. P9 **12,780 ± 140** $\delta^{13}C = -29.7‰$

Wood found in the Kalibari pond of east Dhaka city. It was embedded in a sandy layer overlain by a red bed.

General Comment (H.M.): This series was collected in the Madhupur area of Dakha city. Samples of reworked wood in floodplain deposits were collected, as no other *in-situ*, datable organic material was available. The wood fragments, however, accumulated synchronously with the sediments at the different stratigraphic levels. Thus, these are maximum ages. The fragments indicate that they were deposited by one cycle of transportation. No other age determinations were carried out previously in these deposits; hence, no comparison nor calibration can be made. The ^{14}C dates, however, enabled us to establish a provisional stratigraphic subdivision of the Holocene floodplain deposits (Hussain Monsur 1990).

ARCHAEOLOGICAL SAMPLES

BELGIUM

IRPA-839. KU86-70 — **770 ± 60** — $\delta^{13}C = -29.1‰$

Wood from a beam at Kuringen, Limburg (50°56′45″N, 5°18′34″E). Collected and submitted 1987 by L. van Impe, National Service Excavations, Belgium. The result was used to date the oldest building phase of Prinsenhof mound.

Wijshagen series

Charcoal from Tumulus E at Meeuwen-Gruitrode, Limburg (51°60′22″N, 5°33′16″E), collected and submitted 1987 by L. van Impe. Expected age: 5th century BC.

IRPA-840. 87WH348 — **2160 ± 50**

Sample from Tomb 37. — $\delta^{13}C = -25.4‰$

IRPA-841. 87WH326 — **2025 ± 60**

Sample from Tomb 33. — $\delta^{13}C = -24.9‰$

IRPA-842. 87WH570 — **2245 ± 60**

Sample from Tomb 43. — $\delta^{13}C = -25.2‰$

IRPA-843. 87WH529 — **2320 ± 60**

Sample from a bronze urn. — $\delta^{13}C = -25.1‰$

IRPA-844. 87WH545 — **2300 ± 50**

Sample from a funeral pile. — $\delta^{13}C = -25.9‰$

General Comment (L.v.I.): This was an archaeological investigation of a group of burial mounds, covering cremation graves with Bronze-Age cists and situlae, and also of a group of poor cremation graves. IRPA-843 (charcoal from Situla E) and -844 (charcoal from a surrounding pyre) average 2308 ± 42. A 2 σ calibration gives 69% probability for a date between cal BC 428 and 351.

A date for the burial beneath Mound E, at the end of the 5th or in the first half of the 4th century BC, agrees very well with the youngest archaeological features found in the grave. An ash container dates to a preceding period, and may be considered a "family piece." IRPA-840, -841 and -842 (charcoal from three poor cremation graves, found in the area) suggest a date in the following phase of occupation. A link between the rich mounds with situlae and the group of poor burials, reflecting social differences, cannot be established.

Gouvernementstraat series

Samples from Gent, Oost Vlaanderen (51°03'N, 03°44'E). Since 1987, Dienst Monumentenzorg en Stadsarcheologie has excavated a site between Borreputsteeg and Gouvernementstraat at Gent. The results are important for dating the origin of the city. Collected and submitted Jan. 1988 by M. C. Laleman, Dienst Monumentenzorg en Stadsarcheologie.

IRPA-902. G2 **24,100 ± 1200**

Organic material from Level E, Layer 3. $\delta^{13}C = -29.0‰$

IRPA-904. G4 **1230 ± 40**

Organic material from Level L, Layer 2. $\delta^{13}C = -24.5‰$

IRPA-905. G5 **1000 ± 30**

Organic material from Level H. $\delta^{13}C = -28.6‰$

IRPA-906. G6 **980 ± 40**

Organic material from Level H. $\delta^{13}C = -27.8‰$

Werken series

Samples from excavation of Hoge Andjoen mound at Werkem, Kortemark, west Vlaanderen (51° 1'43"N, 2°57'50"E). Collected and submitted 1988 and 1989 by C. Vanthournout, Gemeentebestuur, Kortemark Belgium (Meulemeester & Vanthournout 1986).

IRPA-913. 87WO3(31A) **1190 ± 30**

Wood (*Quercus*), 13 rings. We do not suspect the old wood effect. $\delta^{13}C = -25.0‰$

IRPA-914. 88WO1(78) **1140 ± 40**

Wood (*Quercus*) from the fill of a pit. $\delta^{13}C = -25.3‰$

IRPA-915. 87WO3(51) **1100 ± 40**

Wood (*Quercus*), 18 rings. The exterior was used for dating. $\delta^{13}C = -24.7‰$

IRPA-916. 87WO3(52) **1090 ± 35**

Wood (*Quercus*), 29 heartwood rings. $\delta^{13}C = -25.5‰$

IRPA-917. 87WO3(31B) **1040 ± 30**

Wood (*Quercus*), 13 rings. We do not suspect the old wood effect. $\delta^{13}C = -26.2‰$

General Comment (C.V.): The dates indicate a very short duration of occupation. The floruit covers a period of only 100 years (cal AD 860–960) (Ottaway 1973). The results give no information about the use of the Hoge Andjoen as a whole, because samples of only three levels were collected. These levels yield dates that form a very coherent series with a spread of only 150 years. The construction of the mound from Floor 2 to Floor 6 occurred in a relatively short time, probably one century (cal AD 860–960). However, it is possible that the dated material was not *in situ*.

Onze-Lieve-Vrouw Cathedral Antwerpen series

Samples from Onze-Lieve-Vrouw Cathedral at Antwerpen (51°13′16″N, 4°23′60″E). Collected Sept. 1987 by M. Van Strydonck and submitted Sept. 1987 by T. Oost, Oudheidkundige Musea, Antwerpen.

IRPA-854. AK-14 **710 ± 200**

Wood from upper Layer 14; North Choir. Diluted; 13.6% sample. $\delta^{13}C = -28.1‰$

IRPA-855. AK-11 **800 ± 60**

Charcoal from calcareous Layer 17; North Choir. Diluted; 54.01% sample. $\delta^{13}C = -26.3‰$

IRPA-856. AK-13 **760 ± 50**

Charcoal from Layer 17; North Choir. $\delta^{13}C = -27.3‰$

IRPA-948. AK-3 **940 ± 40**

Charcoal from under a Roman wall. $\delta^{13}C = -27.0‰$

IRPA-967. AK-6 **980 ± 30**

Twigs from a well. $\delta^{13}C = -28.8‰$

IRPA-972. AK-10 **790 ± 30**

Wood from Wall T; North Choir. $\delta^{13}C = -26.5‰$

General Comment (M.V.S.): Samples were dated to determine different construction phases. Ak-3 and AK-6 represented one construction phase, Samples AK-10, 11, 13 and 14 a younger construction phase. (Van Strydonck, M., Some examples of the use of the Floruit to estimate the duration of archaeological events: Time and environment, ms. in preparation; Van Strydonck, van der Borg & de Jong 1992).

Kooigem series

Samples from the excavation of Kooigem bos at Kortrijk (50°44′45″N, 0°21′E). Collected and submitted 1989 by J. Termote, Vereninging voor Oudheidkundige Bodemonderzoek, west Vlaanderen (Termote 1987). Another date for the same site is IRPA-802: 2300 ± 60 BP (Dauchot-Dehon & Van Strydonck 1989).

IRPA-918. K3 88/20 A **2350 ± 60**

Charcoal from the fill of a channel. $\delta^{13}C = -25.8‰$

IRPA-919. K3 88/20 B **2330 ± 60**

Charcoal from the soil of a channel. $\delta^{13}C = -26.9‰$

IRPA-990. K3 88/20 K2 **2260 ± 60**

Charcoal from the fill of a grain warehouse. $\delta^{13}C = -26.1‰$

Burchtgracht series

Samples from the Burchtgracht excavation at Antwerpen (51°13′16″N, 4°23′60″E). Submitted Aug. 1988 by C. Warmenbol, Antwerpse Vereninging voor bodem en grotonderzoek. Expected age: AD 1200–1500.

IRPA-921.A **680 ± 40**

Wood (*Quercus*) from a pile of the first arch of the sluice system. $\delta^{13}C = -24.9‰$

IRPA-922.B **650 ± 30**

Wood (*Abies*) from a pile of the second arch of the sluice system. $\delta^{13}C = -26.2‰$

IRPA-923.C **640 ± 50**

Wood (*Quercus*) from the fill of a channel. $\delta^{13}C = -25.6‰$

Comment (M.V.S.): Dates construction of the town wall.

Maldegem series

The following results complete the previously published series (Dauchot-Dehon & Van Strydonck 1989) of wood from Roman wells at Maldegem, Oost Vlaanderen (51°13′22″N, 3°25′38″E). Collected and submitted 1989 by H. Thoen, University of Gent, Belgium (Thoen & Vandermoere 1986).

IRPA-970. MAV 88/7/k-f **1770 ± 50**

Branches of wood (*Alnus, Fraxinus*) from Well 4. $\delta^{13}C = -27.6‰$

IRPA-971. MAV 88/7/k-w2 **1870 ± 50**

Board of wood (*Alnus*) from Well 4. $\delta^{13}C = -29.1‰$

IRPA-845. MAV 85/2/D1/N1 **1870 ± 30**

Wood (*Alnus*) from Well 1. $\delta^{13}C = -28.4‰$

General Comment (H.T.): Samples are from a Roman fortified site at Maldegem-Vake, *ca.* AD 175–200. They are waterlogged wood from Wells 1 (IRPA-845) and 4 (IRPA-970, -971). IRPA-970 and -971 agree with the archaeological date. In order to solve the problem of IRPA-673 (Dauchot-Dehon & Van Strydonck 1989: 191), which was too young (1630 ± 50 BP), a new sample, IRPA-845, was dated twice. The new result agrees better with the archaeological date and the averaged radiocarbon date of the previously dated samples.

IRPA-879. Abdij'T Park **305 ± 60** $\delta^{13}C = -25.9‰$

Straw from plaster of a building, Abdij van het Park, at Heverlee, Brabant (50°52′N, 04°42′E).

Collected 1988 by K. Bos and submitted 1986 by R. M. Lemaire, University of Leuven, Belgium. Result agrees with archaeological data.

2430 ± 60
IRPA-910. Hoge weg $\delta^{13}C = -26.8‰$

Organic material from a pile. The result completes a previously published series (Dauchot-Dehon & Van Strydonck 1989: 187-200) from the Hoge weg site at Gent, Oost Vlaanderen (51°3′N, 4°47′E). Collected 1988 by M. Van Strydonck and submitted July 1988 by M. C. Laleman.

4460 ± 60
IRPA-920. L'abri de la Sigillée $\delta^{13}C = -19.6‰$

Human bones from a collective sepulture at Bomal/Ourthe, Luxembourg (50°22′31″N, 5°32′29″E). Collected 1978 and 1986 by J. Dubois and L. Hendrickx and submitted Aug. 1988 by F. Hubert, National Service Excavation, Belgium (Hendrickx & Dubois 1988).

1230 ± 40
IRPA-932. Saint Sauveur $\delta^{13}C = -28.8‰$

Charcoal from Saint Sauveur, Hainaut (50°42′46″N, 3°36′53″E). Collected April 1988 and submitted Nov. 1988 by Ph. Crombé, Geschied en Oudheidkundige kring van Ronse.

TURKEY

Pessinus series

Samples from excavations of the Pessinus Acropolis at Ballihisar, Turkey (39°20′N, 31°35′E). Submitted Dec. 1988 by J. Devreker, University of Gent, Belgium.

IRPA-930. 88/1/4 (38-6) **1930 ± 30**

Wood from Tomb 38. A Roman age was expected. $\delta^{13}C = -23.6‰$

IRPA-931. 88/1/4 (60-1) **1410 ± 40**

Charcoal from Well 60. A Byzantine age was expected. $\delta^{13}C = -24.7‰$

IRPA-940. 89/1/5 55 **1960 ± 30**

Charcoal from Layer 5. $\delta^{13}C = -23.0‰$

IRPA-941. 89/1/5 33 **1860 ± 40**

Charcoal from Layer 4. $\delta^{13}C = -25.6‰$

BALEARIC ISLANDS

Mallorca series

Samples from Mallorca, Spain (39°34′N, 2°44′E), collected and submitted 1988–1989 by W. Waldren, Deya Archaeological Museum and Research Center, Deya Mallorca, Spain.

IRPA-835. ABSM **3700 ± 60**

Charcoal from a Level C enclosure, Pre-talayotic period. $\delta^{13}C = -24‰$

IRPA-836. SMSS **2500 ± 40**

Bone from the Post-talayotic period. $\delta^{13}C = -19.6‰$

IRPA-880. SFO 84 109 **2680 ± 60**

Charcoal from Site SFO YS T4, Phase IV. $\delta^{13}C = -22.4‰$

IRPA-881.SFO 84 115 **2580 ± 60**

Charcoal from Site SFO YS T4, Phase III. $\delta^{13}C = -23.8‰$

IRPA-885. SFO YS HH **2100 ± 60** $\delta^{13}C = -23.3‰$

Charcoal from 0–80 cm depth, in survey Trench WW inside a wall of a hut south of Trench HH.

IRPA-886. SFO YS T2 **680 ± 50**

Charcoal from the entrance floor. $\delta^{13}C = -24.2‰$

IRPA-888. SFO-OS/OSW **1530 ± 50**

Charcoal from Level QD13. $\delta^{13}C = -24.9‰$

IRPA-889. SFO-OS/EW **110 ± 40**

Charcoal from Level Q154. Diluted; 52.6% sample. $\delta^{13}C = -24.5‰$

IRPA-892. SFO-OS/WWE **185 ± 40**

Charcoal from Level QC18. $\delta^{13}C = -24.1‰$

IRPA-893.SFO-OS/SW **1600 ± 50**

Charcoal from Level QAO. $\delta^{13}C = -23.8‰$

IRPA-907. SFO YS T4 **2815 ± 60**

Charcoal from Phase I. $\delta^{13}C = -23‰$

IRPA-908. Sample #1 **3570 ± 70**

Charcoal from Level III 8. Diluted; 73.34% sample. $\delta^{13}C = -25.2‰$

IRPA-909. Sample #2 **3580 ± 60**

Charcoal from Level III 9. $\delta^{13}C = -25.0‰$

IRPA-976. Sample #4 **2960 ± 60**

Charcoal from Quadrant N7-2, Level II. Talayotic period. $\delta^{13}C = -20.5‰$

General Comment (W.W.): Dates agree with archaeological estimates (Waldren 1991).

ECUADOR

IRPA-812. Z3B3-001-107 MC-001

2080 ± 60
$\delta^{13}C = -25‰$

Charcoal from a pit at Cumbaya, Ecuador (0°11′23″S, 78°26′09″W). Collected Oct. 1987 and submitted July 1987 by J. Buys, Ambabel, Quito, Ecuador. Diluted; 71.1% sample. Expected age: 500 BC–AD 1500.

REFERENCES

Baeteman, C. 1989 Quaternary sea-level investigations from Belgium. *Belgium Geological Service Professional Paper* 1989/6(241): 59–91.

Beyens, L. and Chardez, D. 1987 Evidence from testate amoebae for changes in some local hydrological conditions between 5,000 BP and 3,800 BP on Edgeøya (Svalbard). *Polar Researcher* 5(5): 165–169.

Dauchot-Dehon, M. and Heylen, J. 1971 Institut Royal du Patrimoine Artistique radiocarbon dates II. *Radiocarbon* 13(1): 29–31.

Dauchot-Dehon, M. and Strydonck, M. Van 1989 Institut Royal du Patrimoine Artistique radiocarbon dates XIII. *Radiocarbon* 31(2): 187–200.

_____1987 Institut Royal du Patrimoine Artistique radiocarbon dates XII. *Radiocarbon* 29(2): 197–208.

Dauchot-Dehon, M., Strydonck, M. Van and Heylen, J. 1984 Institut Royal du Patrimoine Artistique radiocarbon dates X. *Radiocarbon* 26(3): 384–391.

_____1986 Institut Royal du Patrimoine Artistique radiocarbon dates XI. *Radiocarbon* 28(1): 69–77.

Henderickx, L. and Dubois, J. 1988 L'abri de la Sigillée à Juzaine-Bomal (Province de Luxembourg). *Revue d'Archéologie et de Paléontologie* 5: 7–19.

Hussain Monsur, M. D. (ms.) 1990 Stratigraphical and paleomagnetical studies of some Quaternary deposits of the Bengal Basin, Bangladesh. Ph.D. thesis, Vrije University, Brussels: 241 p.

Meulemeester, J. de and Vanthournout, C. 1986 De "Hoge Andjoen"-motte te Werken. *Archaeologica Belgica* II(1): 105–108.

Ottaway, B. 1973 Dispersion diagrams: A new approach to the display of carbon-14. *Archaeometry* 15(1): 5–12.

Strydonck, M. J. Y. Van, van der Borg, K. and De Jong, A. F. M. 1992 Radiocarbon dating of lime and organic material from buildings. *In* Long, A. and Kra, R. S., eds., Proceedings of the 14th International ^{14}C Conference. *Radiocarbon* 34(3): in press.

Termote, J. 1987 De Keltische hoogtenederzetting van Kooigem bos, de opgravingscampagne 1986. *Westvlaamse Archaeologica* 3(2): 61–72.

Thoen, H. 1988 The Roman fortified Site at Maldegem, 1986 Excavation Report. *Scholae Archaeologicae* 9: 5–78.

Thoen, H. and Vandermoere, N. 1986 The Roman fortified Site at Maldegem, 1985 Excavation Report. *Scholae Archaeologicae* 6: 5–58.

Waldren, W. 1991 Age determination, chronology and radiocarbon recalibration in the Balearic Islands.*In* Proceedings of the 2nd Deya International Conference of Prehistory. Tempus Reparatum. *BAR International Series* 574: 45–57.

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ILLINOIS STATE GEOLOGICAL SURVEY RADIOCARBON DATES X

CHAO-LI LIU[1], *D. L. ASCH*[2], *B. W. FISHER*[1] *and D. D. COLEMAN*[1]

INTRODUCTION

The following is a partial list of samples of archaeological interest processed between February 1981 and October 1985 at the Illinois State Geological Survey (ISGS) Radiocarbon Dating Laboratory. The list contains samples from west-central Illinois that were related to projects conducted by current or former researchers at the Center for American Archeology (CAA) (formerly Foundation for Illinois Archaeology) and Northwestern University, Department of Anthropology, or, as noted, by colleagues from other institutions. Although some of the samples reported here came from non-cultural contexts and are primarily of geological significance, all were from or related to archaeological investigations.

We used the benzene liquid scintillation technique following laboratory procedures previously reported by Coleman (1973, 1974). Ages were calculated on the basis of a ^{14}C half-life of 5568 years, using the NBS oxalic acid standard as reference. Errors (1 σ) reported account only for uncertainties in activity measurements of the sample, standard and backgrounds. If the calculated error is less than 70 years, a minimum value of 70 years is assigned.

Samples submitted by D. L. Asch were precleaned and their contents identified at the CAA Archeobotanical Laboratory. Samples were first processed by a "water flotation" method (Struever 1968; B. W. Styles 1981: 271–273; Wiant 1983), or otherwise washed to remove sediments and to concentrate material to be dated. Most charcoal samples were further cleaned by a "chemical flotation" procedure (Struever 1968; B. W. Styles 1981) in a high-specific-gravity, near-saturated $ZnCl_2$ solution, from which charcoal was separated from denser materials. Identification was performed under the direction of N. B. Asch (see Asch & Asch 1985b: 44–47, for methods). Samples were examined under a dissecting microscope to remove remaining contaminants. Uncarbonized plant material was removed from the charcoal samples to prevent contamination from penetrating rootlets.

Archie series

A Middle Woodland Massey phase habitation site on a hill slope overlooking the valley of Sandy Creek, an Illinois River tributary, in Morgan County, 6 km south of Jacksonville (39°40′50″N, 90°15′50″W). Collected 1976 by J. Gigliotti; submitted by D. L. Asch and K. B. Farnsworth, CAA.

ISGS-966. F 4, Zone 2 — **1900 ± 70**; $\delta^{13}C = -25.5‰$

Dispersed charcoal (90% wood, 10% nutshell) from a refuse pit containing Massey-Fabric-Impressed and Hopewell-series sherds and a Norton point.

ISGS-964. F 5 — **1800 ± 70**; $\delta^{13}C = -25.5‰$

Dispersed charcoal (65% wood, 35% nutshell) from a refuse pit containing a few Massey-Fabric-

[1]Illinois State Geological Survey, Champaign, Illinois 61820 USA
[2]Center for American Archeology, Kampsville, Illinois 62053 USA

Impressed and Hopewell-series sherds.

General Comment (K.B.F.): The utilitarian ceramics at Archie (Massey series) are similar to the Crab Orchard series. The nearby Massey site (see below) had a closely related ceramic assemblage. See Farnsworth and Koski (1985) for the Archie and Massey site reports and definition of the Massey Phase.

9950 ± 260
ISGS-819. Bonaparte, NPH Cr-79, 6.62 m $\delta^{13}C = -27.6‰$

Partially carbonized woody material, probably bark; a non-cultural sample from the Bonaparte site area of Napoleon Hollow archaeological complex; 0.2 m above the base of a 2.5-m-thick laminated slackwater silt unit (LSU-8), beneath colluvium. In Napoleon Valley, 200 m from the Illinois Valley margin, Pike County, 2 km south-southeast of Valley City (39°41′10″N, 90°38′50″W). Collected 1980 and submitted by T. R. Styles, University of Illinois.

Comment (T.R.S.): The pollen from the sediment includes no cold-climate taxa. LSU-8 probably is equivalent to slackwater deposits under the Keach School terrace in Illinois Valley. See T. Styles (1985) for a discussion of the Holocene and Late Pleistocene geology of this locality.

Campbell Hollow series

An Early/Middle Archaic and Late Woodland habitation site on a Campbell Hollow hill-slope swale; near the Illinois Valley margin in Scott County, 7 km south-southwest of Bluffs (39° 41′10″N, 90°34′00″W). Late Woodland pit features were at the base of the plow zone; an upper Archaic occupation unit was overlain by ~2 m of colluvial sediment; a lower Archaic occupation was 30–40 cm below the upper Archaic unit. Submitted by C. R. Stafford, CAA, and D. L. Asch.

8350 ± 100
ISGS-891. U6 (RC #100) $\delta^{13}C = -26.0‰$

Charcoal fragments (95% wood, 5% nutshell) dispersed across a 14-m-long area of the lower Archaic midden (Squares 20, 21, 23–38, 45; Feature 12); extracted by flotation from 3.5 m^3 of sediment. Collected 1980–1981 by C. R. Stafford.

7670 ± 90
ISGS-936. Square 62, Levels 2–4; F 23 & A/C $\delta^{13}C = -25.8‰$

Carbonized nutshell fragments (mostly *Juglans nigra*) dispersed within a 20-cm-thick unit of a 2 × 2-m excavation area (including midden, a shallow pit and a hearth), within an upper Archaic midden. Collected 1981 by C. R. Stafford.

7600 ± 110
ISGS-753. Square 23, Levels 2A, 3 $\delta^{13}C = -25.4‰$

Charcoal fragments (50% wood, 50% nutshell), probably from a single depositional episode in the upper Archaic midden. Collected 1980 by C. R. Stafford.

7560 ± 80
ISGS-940. Square 30, Levels 4–6; F 13, 16, 19 $\delta^{13}C = -26.4‰$

Charcoal fragments (80% wood, 20% nutshell) scattered across 4 m of the upper Archaic occupation, from a midden and fill of three shallow pits. Collected 1980 by C. R. Stafford.

ISGS-947. F 3 **1250 ± 70**
$\delta^{13}C = -25.9‰$

Charcoal (>99% wood and bark fragments, mostly *Quercus*) dispersed throughout a Late Woodland refuse pit containing discoidal and grit-tempered pottery decorated with a punctate band around an angular shoulder (Bauer Branch series). Collected 1980 by M. B. Sant, CAA.

ISGS-899. F 2, Level 4B **1240 ± 70**
$\delta^{13}C = -25.9‰$

Dispersed charcoal (90% wood, 10% nutshell), from a Late Woodland refuse pit. Bauer Branch pottery is represented among the sherds. Collected 1979 by M. B. Sant.

General Comment (C.R.S.): The upper and lower Archaic occupations (see Stafford 1985) were short-term encampments. Expanding-stem forms predominate in the upper Archaic projectile point assemblage; no points were recovered from the older Archaic unit.

Cypress Land series

A multicomponent habitation site located along the margin of the Keach School terrace in the Illinois Valley, Greene County, 8 km north-northwest of Eldred (39°21′30″N, 90°35′00″W). An unstratified midden created by the churning of prehistoric and historic cultural materials into loose sands overlies the cultural features. Collected 1978 by B. Yaegel; submitted by D. L. Asch.

ISGS-790. Test Square 7, Level 4A **4810 ± 70**
$\delta^{13}C = -25.4‰$

Dispersed charcoal fragments (>99% nutshell) from a midden overlying a pottery-containing pit.

Comment (D.L.A.): The dated nutshell is much older than the Early Woodland pit contents, and most or all the nutshell must have been redeposited.

ISGS-791. F 6B, Levels 3–4 **4750 ± 80**
$\delta^{13}C = -25.3‰$

Dispersed charcoal fragments (>95% nutshell) from the lower levels of a pit feature. A small, side-notched Archaic point was recovered from the basal pit fill; two potsherds and a pig patella were recovered from the top of the feature.

ISGS-1167. F 10 **4610 ± 70**
$\delta^{13}C = -26.8‰$

Dispersed carbonized *Carya* nutshell fragments from a pit. One potsherd was recovered from the top of the feature.

ISGS-1016. F 7 **2270 ± 70**
$\delta^{13}C = -25.9‰$

Dispersed charcoal fragments (>99% wood, <1% nutshell) from a Cypress phase (Black Sand) Early Woodland pit containing eight Liverpool cordmarked potsherds.

Comment (D.L.A.): Because the charcoal from the surrounding midden was >90% nutshell, it seemed likely that the charcoal comprising the ^{14}C sample was not redeposited. The date accords with the chronology of the Cypress phase.

General Comment (D.L.A.): Despite somewhat questionable contexts due to the disturbance of the midden and upper levels of pits at the base of the midden, the three nutshell samples had nearly the same ^{14}C age, as did the nutshell sample from the nearby Cypress Land South shell midden (see below). Apparently, most of the nutshell at Cypress Land came from a 5th millennium BP Archaic occupation, an interpretation consistent with the predominance of Matanzas and Matanzas-like forms in the projectile point assemblage. See Conner (1986).

ISGS-792. Cypress Land South, TS-1, Levels 1B, 2, 2NW, 3 **4500 ± 120**

Dispersed charcoal fragments (>95% nutshell) from a shell midden at the Keach School terrace margin in the Illinois Valley, Greene County, 7 km north-northwest of Eldred (39°21′10″N, 90°35′00″W), from 0.2–0.4 m depth (the base of the plow zone to the near-base of the shell pile). Base leach was omitted. Collected 1978 by G. L. Houart; submitted by D. L. Asch.

Comment (D.L.A.): Temporally diagnostic cultural materials have not been recovered from the ~20-m-diameter shell midden. The mussels are river species, suggesting shells were deposited when the active channel of the Illinois River (now 3 km to the west) was adjacent to the terrace.

Deer Track series

A late Woodland habitation site in Bear Creek Valley, a Mississippi River tributary, Adams County, 2 km north of Marcelline (40°08′30″N, 91°22′00″W). Collected from fills of refuse pits at the base of the plow zone (Feature 53 underlying an additional 15 cm of laminated sands). Collected 1978 by C. R. McGimsey and G. L. Houart; submitted by D. L. Asch.

ISGS-785. F 53 **1370 ± 70**
$\delta^{13}C = -25.4‰$

Dispersed charcoal fragments (67% wood, 33% nutshell) from a pit containing a Klunk side-notched arrow point and Sepo-type pottery only. Two fragments of maize were recovered from the pit fill.

Comment (D.L.A.): This is the oldest dated record for maize from a secure context in west-central Illinois (Asch & Asch 1985a).

ISGS-779. F 30 **1220 ± 70**
$\delta^{13}C = -25.8‰$

Dispersed, carbonized *Carya* nutshell fragments from a pit containing 67 Sepo-type sherds. No maize was in the pit.

ISGS-777. F 20, Levels 1, 2 **1220 ± 70**
$\delta^{13}C = -25.8‰$

Dispersed charcoal fragments (90% wood, 10% nutshell) from a pit containing 21 Sepo-series potsherds, 1 Canton-series sherd, and 2 sherds with lenticular punctate decoration. No maize was in the pit.

ISGS-782. F 46, Level 0 **1110 ± 70**
$\delta^{13}C = -26.5‰$

Dispersed wood charcoal fragments from a pit containing 62 Sepo sherds and 3 Canton sherds. Maize fragments were numerous.

General Comment (D.L.A.): McGimsey and Conner (1985) assign the ceramics from the site to the Sepo series, which comprises almost all of the recovered sherds, and to the Canton series ("Maples Mills"), which was uncommon even in the few features containing it. However, revisions of Sepo and Canton ceramic classifications and chronology for the central Illinois Valley, where these series originally were defined, may require reevaluation of Deer Track's cultural affiliation (Esarey 1988; Harn 1986). The dates support the idea that Canton pottery was present only during the later part of occupation. Increasing dependence on maize through time at Deer Track may be reflected by its greater abundance in features containing Canton pottery.

ISGS-872. Dickson Camp, F 5 **2040 ± 90** *$\delta^{13}C$ = −25.6‰*

Dispersed, carbonized hazelnut shell fragments from Fulton County, 6 km southeast of Lewistown (40°21′00″N, 90°07′00″W) in a prehistoric midden remnant (designated Feature 5) at the base of the plow zone. The site is located on a hill slope at the juncture of the Illinois and Spoon River Valleys. Collected 1965 by J. R. Caldwell; submitted by D. L. Asch and A-M. Cantwell, New York University.

Comment (D.L.A.): Dickson Camp is an early Havana tradition (Morton/Caldwell phase) habitation site, with minor subsequent Mississippian occupations (Cantwell 1980). Other dates from Feature 5 are 1640 ± 90 BP (I-2025) and 270 ± 85 (I-2026), both too recent to date the Morton/Caldwell component. The hazelnut charcoal fraction was selected to make up ISGS-872, because this nutshell is peculiarly common in Havana cultural contexts in the region (Farnsworth & Asch 1986: 423). See also *Comment* for the Pond site, below (ISGS-873).

Hillview Levee and Drainage District series

From Illinois Valley alluvium; submitted by E. R. Hajic and D. L. Asch.

ISGS-1122. LLC 40, 5.82–6.00 m **9300 ± 150** *$\delta^{13}C$ = −28.1‰*

Uncarbonized, porous wood, bark and much fine, partially decomposed plant matter, 5.82–6.00 m below ground surface from an unnamed silty clay to a silty clay loam unit, 3 km south-southeast of Bedford (39°31′10″N, 90°32′50″W). Collected 1982 by E. R. Hajic.

Comment (E.R.H.): From slackwater sediments filling the Swan Lake paleochannel sediment assemblage (Hajic 1987, 1990b).

ISGS-1095. LLC 55, 9.09–9.15 m **5000 ± 70** *$\delta^{13}C$ = −28.2‰*

Uncarbonized section of a *Betula* branch, 9.09–9.15 m below ground surface from the base of the Wood Lake paleochannel sediment assemblage from Scott County, 2 km northwest of Bedford (39°32′20″N, 90°33′50″W). Early Woodland cultural materials were found at ground surface. Collected 1982 by E. R. Hajic.

ISGS-1120. LLC 11B, 5.98–6.00 m **2420 ± 70** *$\delta^{13}C$ = −29.1‰*

Uncarbonized, diffuse porous wood and much fine, partially decomposed plant matter, from a 2-cm-thick bed of organics, 5.98–6.00 m below ground surface, at the middle of a sand-to-silty-clay gradational sequence infilling a floodbasin slough or yazoo stream channel, which belongs to the submodern channel sediment assemblage, from Greene County, 5 km north of Hillview (39° 29′30″N, 90°32′00″W). Collected 1983 by D. S. Leigh.

Comment (E.R.H.): Dates the approximate time of the initial infilling of the slough; ISGS-1084 dates the top of this unit.

1980 ± 80
$\delta^{13}C = -27.7‰$

ISGS-1084. LLC 11A, 3.78–3.98 m

Primarily uncarbonized bark, non-woody plant debris and some wood (*Platanus, Ulmus, Carya* and unidentifiable diffuse porous), 3.78–3.98 m below ground surface at the top of a sand-to-silty-clay gradational sequence infilling a floodbasin slough or yazoo stream channel, which belongs to the submodern channel sediment assemblage, 10 m from LLC-11B (ISGS-1120). Collected 1982 by E. R. Hajic.

General Comment (E.R.H.): See Hajic (1987, 1990b) for further description and interpretation.

Koster (North Field) series

A multicomponent, stratified prehistoric habitation site on a colluvial fan and underlying alluvial fan of Koster Creek, Illinois Valley margin, Greene County, 7 km northeast of East Hardin (39°12′30″N, 90°33′00″W). Submitted by J. A. Brown, Northwestern University, and D. L. Asch, except as noted.

13,360 ± 100
$\delta^{13}C = -25.8‰$

ISGS-875. EMC 9, 12.40–12.55 m

Uncarbonized conifer (*Picea*?) wood and bark from sandy silt underlying a reddish-brown clay unit, all part of a slackwater/fluvial complex at the Illinois Valley margin, underlying Holocene alluvial fan deposits of Koster Creek and colluvium. The Holocene deposits contain stratified cultural remains. Collected 1979 by E. R. Hajic; submitted by E. R. Hajic and D. L. Asch.

Comment (E.R.H.): A second date, 12,320 ± 80 BP (ISGS-415), pertains to the same fluvial complex (Butzer 1977: 49; Liu, Riley & Coleman 1986a: 81). Red clays are traced laterally across the Illinois Valley, where they occur in Deer Plain (savanna) Terrace sediments (Hajic 1985). See Hajic (1990a, b) for further treatment of Koster geology.

8130 ± 90
$\delta^{13}C = -25.5‰$

ISGS-1065. F 222, Levels B–D

Dispersed charcoal (60% wood, 40% nutshell) from a large pit feature containing a dog burial in Horizon 11, 8.45–8.80 m below the primary reference datum. Collected 1970 by S. Struever, Northwestern University.

Comment (J.A.B.): This rerun of F 222 and other cultural evidence suggests that previous dates on material from this feature are anomolous (GX-2102: 7155 ± 220 BP, Levels A–C; GX-2103: 7105 ± 360 BP, Level I). Though slightly more recent than anticipated, the present assay conforms reasonably well with the ISGS chronology.

8230 ± 120
$\delta^{13}C = -26.0‰$

ISGS-783. F 2032 & 2201, Squares 360 & 361

Dispersed charcoal (>95% wood, <5% nutshell) from parts of a hearth and surrounding occupation area (Levels 43 and 45B of Sequence 360, Levles 45, 46A and 46B of Sequence 361) in Horizon 10A, 6.52–6.85 m below the primary reference datum. Collected 1975 by G. L. Houart.

ISGS-923. F 2041, Levels AB, BB, CB; Square 178, Level 56B **7920 ± 150** $\delta^{13}C = -25.1‰$

Dispersed charcoal (>95% wood, some nutshell) from a hearth and surrounding charcoal scatter, Horizon 9B, 5.49–5.73 m below the site datum. Collected 1974 by G. L. Houart.

ISGS-859. F 1396 & 1397 **7320 ± 70** $\delta^{13}C = -25.6‰$

Dispersed charcoal (~50% nutshell, 50% wood) from two cultural features (hearths?) located <1 m apart, Horizon 8D, 3.02–3.25 m below the site datum (~5.3 m below ground surface). Collected 1971 by J. W. Mueller and S. Struever.

ISGS-800. Square 46, Levels 31–32 **6970 ± 150**

Dispersed charcoal (~50% nutshell, 50% wood) from a midden level assigned to Horizon 8C, 1.12–1.28 m below the site datum (~4.2 m below ground surface). Collected 1971 by J. W. Mueller and S. Struever.

ISGS-809. Square 46, Level 26 **7000 ± 80** $\delta^{13}C = -25.7‰$

Dispersed charcoal (~50% nutshell, 50% wood) from a midden level assigned to Horizon 8B, 0.68–0.76 m below the site datum (~3.7 m below ground surface). Collected 1971 by J. W. Mueller and S. Struever.

ISGS-1082. F 1387 **6910 ± 100** $\delta^{13}C = -25.1‰$

Dispersed charcoal (~50% wood, 50% nutshell) from a feature in Horizon 8B, 1.30–1.45 m below the site datum. Base leach was omitted. Collected 1971 by J. W. Mueller and S. Struever.

Comment (J.A.B.): The date is in excellent agreement with two others run on material from the same archaeological component, Horizon 8B (ISGS-835, -848, below). The result strongly suggests that a previous Geochron assay on charcoal from F 1387 is erroneous (GX-2402: 7730 ± 190 BP, H. W. Kreuger, personal communication 1971).

ISGS-848. Square 254, Levels 14–15 **6960 ± 80** $\delta^{13}C = -25.2‰$

Dispersed charcoal (~75% nutshell, 25% wood) from Horizon 8B midden, 3.36–3.52 m below the site datum. Collected 1972 by R. B. McMillan.

ISGS-835. Square 254, Levels 11–12 **6860 ± 80** $\delta^{13}C = -24.7‰$

Dispersed charcoal (>90% nutshell, some wood) from Horizon 8A midden, 3.14–3.28 m below the site datum. Collected 1972 by R. B. McMillan.

ISGS-1000. Square 112, Level 27 **6510 ± 310** $\delta^{13}C = -25.8‰$

Dispersed charcoal (~67% nutshell, 33% wood) from Horizon 8B midden, 1.24–1.33 m below the site datum. Base leach was omitted. Collected 1971 by J. W. Mueller and S. Struever.

Comments (J.A.B.): Run as a test of a questionably young Geochron date from the same square and level (GX-2401: 6265 ± 180 BP, H. W. Kreuger, personal communication 1971). (D.D.C.): The date includes a correction factor because carbon was detected in the lithium metal used in the benzene synthesis. The correction factor causes the relatively high standard deviation. Other samples from this date list that were processed with the contaminated lithium are ISGS-989, -1001 and -1003.

ISGS-1136. Square 112, Levels 24–26 **6990 ± 70** $\delta^{13}C = -25.6‰$

Dispersed charcoal (55% nutshell, 45% wood) from Horizon 8A/8B midden, 0.86–1.14 m below the site datum. Collected 1971 by J. W. Mueller and S. Struever.

Comment (J.A.B.): The sample was run as a recheck of other samples (ISGS-1000 and GX-2401) from underlying midden Level 27 of Square 112. The present assay agrees well with other dates for Horizons 8A and 8B.

ISGS-956. Square 411, Levels 5–8 **2980 ± 70** $\delta^{13}C = -25.3‰$

Dispersed charcoal (80% wood, 20% nutshell) from an aceramic midden unit assigned to Horizon 4A, 0.69–1.00 m below ground surface, north of the "macroblock" excavation area. Collected 1974 by G. L. Houart.

Comment (D.L.A.): An admixture of charcoal from an older Titterington component and a younger Late Woodland/Mississippian occupation is suspected because the site has yielded almost no diagnostic artifacts at the 3000 BP time horizon, and an accelerator mass spectrometric (AMS) age of 600 ± 400 BP (NSRL-296), from the Rochester Nuclear Structure Research Laboratory, was obtained on carbonized maize from Square 411, Level 12, 1.23–1.31 m below ground surface (Conard *et al.* 1984).

ISGS-1205. F 2008, Levels B–C **970 ± 70** $\delta^{13}C = -26.1‰$

Dispersed hickory nutshell from a pit 0.15 m beneath the plow zone. The pit contained Jersey Bluff and Mississippian potsherds. Collected 1974 by G. L. Houart.

General Comment (J.A.B.): Other Koster site dates are reported and discussed in Brown and Vierra (1983), Coleman and Liu (1975: 170–171), Liu, Riley and Coleman (1986a: 80–81), Conard *et al.* (1984) and Hajic (1990a).

Koster East series

A multicomponent habitation site with a major occupation by Early Bluff and Late Bluff Late Woodland components; on the margin of a high terrace overlooking the Illinois River floodplain, Greene County, 7 km northeast of East Hardin (39°12′30″N, 90°32′50″W). Collected 1971 by J. P. Nicholas, Northwestern University; submitted by D. L. Asch.

ISGS-1003. F 1100, Level C **980 ± 190** $\delta^{13}C = -26.5‰$

A concentration of carbonized acorn (*Quercus*) shells, kernels and caps; from a pit containing 255 sherds classified as Early Bluff and 1 Late Bluff sherd. Maize was not recovered from the pit.

Comment (D.D.C.): See *Comment* for ISGS-1000, above.

ISGS-1024. F 1100, Levels D–K **1330 ± 70** $\delta^{13}C = -26.6‰$

Dispersed charcoal (85% wood, 15% nutshell) from the lower levels of an Early Bluff pit.

Comment (D.L.A.): Submitted as a check for ISGS-1003. This date was expected for an Early Bluff component; ISGS-1003 is too recent.

ISGS-1001. F 1040, Level B & ash concentration **930 ± 200** $\delta^{13}C = -26.5‰$

Dispersed charcoal (30% nutshell, 70% wood) from a pit containing 108 Late Bluff sherds and 8 Early Bluff sherds. Maize was present.

Comment (D.D.C.): See *Comment* for ISGS-1000, above.

ISGS-1020. F 1040, Levels D–G **1120 ± 70** $\delta^{13}C = -26.3‰$

Dispersed charcoal (>90% wood, <10% nutshell) from the lower levels of a Late Bluff pit.

Comment (D.L.A.): Submitted as a supplement to contaminated sample, ISGS-1001, from F 1040. The Koster East Late Bluff occupation should be older than "Jersey Bluff" occupation downslope from Koster East at the Koster (North Field) site, where Jersey Bluff and shell-tempered ceramics occur together (Koster North date, ISGS-1207: 1700 ± 70, C. L. Liu, personal communication). ISGS-1020 probably is a better estimate of the age of the Late Bluff occupation at Koster East than the corrected date, ISGS-1001.

General Comment (D.L.A.): Late Bluff pottery at the site shows S-twist cord impressions; Late Bluff pottery shows Z-twist impressions. Other dates obtained on Late Woodland charcoal from the site are 1645 ± 100 BP (GX-2400): F 1070, Level F (too old); and 1330 ± 100 (GX-2399): F 1133, Level A (H. W. Kreuger, personal communication 1971).

Kuhlman Habitation series

A Late Archaic (Titterington phase) and Late Woodland habitation area on a blufftop overlooking the Mississippi Valley, Adams County, 1 km north of Fall Creek (39°47′30″N, 91°18′20″W). See Hassen (1985) and Morgan (1985). Collected by H. Hassen, CAA; submitted by H. Hassen and D. L. Asch.

ISGS-982. F 133, Level 1 **4010 ± 130** $\delta^{13}C = -25.9‰$

Carbonized nutshell from a Titterington-phase pit containing three Wadlow/Sedalia blades and 8 kg of chert tool manufacturing debris. Base leach was omitted. Collected 1980.

Comment (D.L.A.): The date is consistent with Titterington-phase dates from other sites, despite low-level Late Woodland contamination of F 133 pit fill, indicated by the recovery of a single maize fragment. The nutshell was used to estimate the age of this feature, because it is very sparsely represented in Late Woodland contexts at the site. *Curcurbita* rind fragments were also recovered from the pit.

ISGS-805. F 51, Levels 2–5 — **920 ± 70**; $\delta^{13}C = -25.8‰$

Dispersed charcoal (>95% wood, <5% nutshell) from a Late Woodland pit. Collected 1979.

Comment (H.H.): Ceramics from F 51 included two restorable vessels. One of these is castellated, cordmarked, and has plain dowel impressions along the top of the lip. The second is a bowl with a cordmarked exterior. The pit also contained a partially articulated dog skeleton.

ISGS-864. F 71, Levels 2–4 — **1190 ± 70**; $\delta^{13}C = -24.2‰$

Dispersed charcoal (77% wood, 17% maize, 6% nutshell) from a Late Woodland refuse pit. Collected 1979–1980.

Comment (H.H.): The pit contained Late Woodland ceramics, including a single-cord-impressed rimsherd and several rimsherds with a plain dowel, a cord-wrapped stick and jointed grass-stem lip impressions.

Kuhlman Mound Group series

A Late Woodland mound group adjacent to the Kuhlman habitation site on a blufftop overlooking the Mississippi Valley, Adams County, 1 km north of Fall Creek (39°47′20″N, 91°18′20″W). Collected 1980 by K. A. Atwell; submitted by K. A. Atwell and D. L. Asch.

ISGS-874. Mound 4, North lobe, Unit 4/6, Level 2, #39 — **1360 ± 70**; $\delta^{13}C = -25.5‰$

A single piece of charcoal (*Quercus* subgenus *Lepidobalanus*), 20 cm below present ground surface, in an earth-capped, limestone-walled, collapsed burial structure, collected between burned limestone rocks forming a "pavement" over human cremations on the original ground surface. Two ceramic elbow pipes were found in the structure; single-cord-impressed pottery was present elsewhere in the mound.

ISGS-833. Mound 4, North lobe, Unit 4/5, Level 2, #37 — **1330 ± 70**; $\delta^{13}C = -26.3‰$

A single piece of charcoal (*Quercus* subgenus *Lepidobalanus*), 24 cm below present ground surface, atop "pavement" rocks of the charnel structure, 60 cm from ISGS-874.

General Comment (D.L.A.): ISGS-874 and -833 may be from the same piece of wood. Conner (1984) and Atwell and Conner (1991) reported ^{14}C ages on collagen from human skeletal material in Kuhlman Mound 1 (UCR-1415, 1210 ± 90 BP) and Kuhlman South Ridge Ossuary (UCR-1414, 1300 ± 90 BP, R. E. Taylor, personal communication 1982).

Lagoon series

A Titterington-phase habitation site on alluvium below bluffs at the western margin of the Illinois Valley and mouth of Crawford Hollow, in Calhoun County, 2 km south of Kampsville (39°

16′50″N, 90°36′40″W). The samples were taken from shallow refuse pits. Collected 1978 by L. Bartram; submitted by D. L. Asch and T. G. Cook.

ISGS-804. F 100, Level B **4030 ± 70**
$\delta^{13}C = -26.0‰$

Dispersed charcoal fragments (>90% wood, <10% carbonized nut and acorn shell) from the lower part of the pit fill, 10–20 cm beneath the plow zone.

ISGS-798. F 104, Level B **4010 ± 150**
$\delta^{13}C = -26.0‰$

Dispersed charcoal fragments (75% wood, 25% nutshell) from the lower part of the pit fill, 16–32 cm beneath the plow zone.

General Comment (T.G.C., D.L.A.): The plow zone contained Late Archaic (Titterington) occupational debris, and a very light Late Woodland and Mississippian scatter. Features 100 and 104 lacked culturally diagnostic debris, but the ages fall within the recognized span of the Titterington phase. A carbonized *Cucurbita* rind from another pit containing a Sedalia point yielded an AMS date of 2300 ± 600 BP (NSRL-303) (Conard *et al.* 1984).

Massey series

A Middle Woodland Massey phase habitation site on a hillside overlooking Sandy Creek Valley, an Illinois River tributary, in Morgan County, 6 km south-southeast of Jacksonville (39°40′50″N, 90°16′30″W). See Farnsworth and Koski (1985). Collected 1976 by J. Gigliotti; submitted by D. L. Asch and K. B. Farnsworth.

ISGS-963. F 11, Levels 2–4 **1930 ± 70**
$\delta^{13}C = -25.5‰$

Dispersed charcoal (90% wood, 10% nutshell) from a refuse pit containing Massey, Hopewell and Baehr series pottery.

ISGS-965. F 1, Levels 1–2 **1750 ± 70**
$\delta^{13}C = -25.5‰$

Dispersed charcoal (90% wood, 10% nutshell) from a refuse pit containing a Massey Fabric-Impressed pottery vessel.

General Comment (K.B.F.): Massey appears to have been occupied by a single household; a lengthy occupation is improbable. Utilitarian Massey series ceramics are similar to those of the Crab Orchard series. The nearby Archie site, above, had a closely related occupation.

ISGS-1264. Mauvaise Terre Creek paleochannel, MVT 1B **9750 ± 70**
$\delta^{13}C = -28.1‰$

Primarily uncarbonized, nonconiferous (diffuse porous and ring porous) wood and bark, some herbaceous plant debris, 4.67–4.80 m below ground surface in the Illinois Valley; near the base of a stratified and laminated silt unit filling an old meander channel of Mauvaise Terre Creek, incised into the Keach School Terrace; from Scott County, 5 km southwest of Oxville (39°40′50″N, 90° 37′00″W). Collected 1983 by D. S. Leigh; submitted by E. R. Hajic, D. S. Leigh and D. L. Asch.

Comment (E.R.H.): This date provides a minimum age for the Keach School Terrace. See Hajic (1987, 1990b).

ISGS-1263. Meredosia Lake Levee and Drainage District, DLC 12A-F **14,300 ± 290** $\delta^{13}C = -26.9‰$

Uncarbonized conifer wood and bark, abundant *Picea* needles and a few *Abies* needles, and herbaceous plant debris, 3.40–3.65 m below ground surface, from the base of slackwater silt in the Bug Island paleochannel sediment assemblage, beneath eolian sand, from Cass County, 8 km north-northeast of Meredosia (39°53′30″N, 90°31′10″W). Base leach was omitted. Collected 1984 by D. S. Leigh; submitted by E. R. Hajic, D. S. Leigh, and D. L. Asch.

Comment (E.R.H.): Bath Terrace and the Bug Island paleochannel cutting it probably developed in response to the Kankakee Torrent. See Hajic (1987, 1990b).

Meredosia Village Levee and Drainage District series

From Illinois Valley alluvial sediments. Collected by D. S. Leigh; submitted by E. R. Hajic, D. S. Leigh and D. L. Asch.

ISGS-1285. MLC 9B–D, 7.10–7.15 m **14,590 ± 240** $\delta^{13}C = -27.3‰$

Uncarbonized wood (mostly coniferous, some diffuse porous), bark, herbaceous plant debris and *Picea* needles, 7.10–7.15 m below ground surface from slackwater silt in the Bug Island paleochannel sediment assemblage, beneath alluvial fan silt, from Morgan County, 4 km east-southeast of Meredosia (39°49′10″N, 90°31′00″W). Base leach was omitted. Collected 1984.

Comment (E.R.H.): See *Comment* for ISGS-1263, above.

ISGS-1283. MLC 9A–C, 6.90–7.05 m **12,360 ± 240** $\delta^{13}C = -28.0‰$

Uncarbonized conifer wood and bark, herbaceous plant debris, seeds (primarily *Polygonum* and *Cyperaceae*) and *Picea* needles; 6.90–7.05 m below ground surface, collected from samples above ISGS-1285, in the same sediment unit.

ISGS-1262. MLC 34, 3.19–3.77 m **13,360 ± 240** $\delta^{13}C = -27.4‰$

Uncarbonized herbaceous plant debris, some conifer wood and bark, abundant *Picea* needles and a few *Abies* needles, 3.19–3.77 m below ground surface from laminated silt interstratified with fine sand in the Bug Island paleochannel sediment assemblage, beneath upland-derived silt, from Morgan County, 4 km east-northeast of Meredosia (39°50′40″N, 90°30′50″W). Collected 1983.

Comment (E.R.H.): The sample was recovered at or near the transition from glaciofluvial to lacustrine sediments of the Bug Island paleochannel sediment assemblage (Hajic 1987, 1990b).

ISGS-1284. MLC 24B–D, 4.40–4.50 m **13,340 ± 180** $\delta^{13}C = -27.5‰$

Uncarbonized herbaceous plant debris, conifer wood, seeds (mostly *Cyperaceae* and *Potamogeton)* and *Picea* needles, 4.40–4.50 m below ground surface from slackwater silt in the

Bug Island paleochannel sediment assemblage, beneath alluvial fan silt, from Morgan County, 4 km southeast of Meredosia (39°48′20″N, 90°31′40″W). Collected 1984.

Comment (E.R.H.): See *Comment* for ISGS-1262, above.

ISGS-1282. MLC 29, 4.50 m **9830 ± 160**
$\delta^{13}C = -27.7‰$

Uncarbonized wood and bark, 4.50 m below ground surface, from fine and medium sand with silt and clay laminae in the Bug Island paleochannel sediment assemblage, underlying laminated slackwater silt and upland-derived silty alluvium, from Morgan County, 2 km northeast of Meredosia (39°50′40″N, 90°32′00″W). Collected 1983.

Comment (E.R.H.): Indicates intermittent fluvial reactivation on the western side of the Bug Island paleochannel system.

ISGS-1286. MLC 57, 1.40–1.45 m **1780 ± 70**
$\delta^{13}C = -28.0‰$

Bulk sample of peaty, silt loam, 1.40–1.45 m below surface in the Bug Island paleochannel sediment assemblage, from Scott County, 3 km north-northwest of Bluffs (39°46′50″N, 90°33′00″W). Base leach was omitted. Collected 1983.

Comment (E.R.H.): Dates marshy conditions in the paleochannel, providing a minimum age that the paleochannel could have been active.

General Comment (E.R.H.): Dates from Meredosia Village and Meredosia Lake Districts (except ISGS-1286) should approximately span the interval of fluvial activity of the Bug Island paleochannel system. See Hajic (1987, 1990b).

Napoleon Hollow series

A multicomponent, stratified habitation site on the Illinois River floodplain and an adjacent colluvial fan, Pike County, 2 km south-southeast of Valley City (39°41′10″N, 90°38′40″W, except Square 216 and Block IV samples at 39°41′20″N, 90°38′40″W). Collected by M. D. Wiant, CAA; submitted by M. D. Wiant and D. L. Asch.

ISGS-814. Square 54, Level 3NW (RC #33) **7050 ± 140**
$\delta^{13}C = -27.0‰$

An intact, partially decomposed, carbonized log (*Quercus* subgenus *Lepidobalanus*), from the prograding end of the colluvial fan in a stratum containing Middle Archaic and some Early Archaic artifacts, beneath 2.0 m of colluvial and alluvial sediment. Collected 1980.

Comment (D.L.A.): The sample splintered into very fine fragments when washed; the carbon content of the cleaned sample was unusually low (~28%).

ISGS-786. Square 36, Level 46 **6630 ± 100**
$\delta^{13}C = -25.8‰$

Dispersed charcoal (85% wood, the remainder wood and tuber) from the Middle Archaic stratum (Napoleon component) of the colluvial fan, 2.3 m below ground surface (Block II). Collected 1979.

Comment (D.L.A.): *Cucurbita* rind from this provenience yielded an AMS date of 7000 ± 250 (NSRL–299) (Conard *et al.* 1984).

6800 ± 80
$\delta^{13}C = -25.8‰$

ISGS-817. Square 36, Levels 42A, 43A

Dispersed charcoal (67% nutshell, the remainder wood and tuber) from the Middle Archaic stratum (Napoleon component) of the colluvial fan, 2.1 m below ground surface (Block II). Collected 1979.

Comment (D.L.A.): Level 42A flotation sample contained a single *Cucurbita* rind fragment.

6730 ± 70
$\delta^{13}C = -25.4‰$

ISGS-937. Square 77, Levels 42B, 43B, 44B

Dispersed charcoal (67% nutshell, 33% wood) from the Middle Archaic stratum (Napoleon component) in a colluvial fan, 3.2 m below ground surface (Block II). Collected 1980.

6710 ± 170
$\delta^{13}C = -26.2‰$

ISGS-949. Square 1007, Levels 20A, 21A, 22A

Dispersed charcoal (85% wood, 15% nutshell) in a shallow basin or natural depression on the floodplain, buried by 2.0 m of colluvium and alluvium. Base leach was omitted.

Comment (M.D.W.): The sample was associated with scatter of Archaic cultural debris, mainly Middle Archaic, but including a few Early Archaic projectile points. Collected 1979.

6130 ± 110
$\delta^{13}C = -28.3‰$

ISGS-909. F 36, Levels 2P, 3

Dispersed charcoal (85% nutshell, 15% wood) from a shallow pit in colluvium, 1.6 m below ground surface, excavated from the surface of a limestone "pavement," marking the uppermost, eroded surface of the Helton Middle Archaic cultural stratum (Block II). Collected 1980.

6080 ± 90
$\delta^{13}C = -25.8‰$

ISGS-972. F 116 (Square 84, Level 36C)

Dispersed charcoal (90% nutshell, 10% wood) from a hearth in colluvium, at the base of the Helton Middle Archaic midden, 2.0 m below ground surface (Block II). Collected 1980.

5670 ± 90
$\delta^{13}C = -26.2‰$

ISGS-806. Square 77, Level 24B

Dispersed carbonized nutshell fragments from the Middle Archaic stratum (Helton component) of the colluvial fan, 0.7 m below ground surface (Block II). Collected 1980.

5350 ± 70
$\delta^{13}C = -24.6‰$

ISGS-938. F 38, Level 1

Dispersed charcoal (>99% nutshell) from the Middle Archaic stratum (Helton component) of the colluvial fan, 2.3 m below ground surface (Block II). Collected 1980.

Comment (D.L.A.): A flotation sample from the feature contained *Cucurbita* rind.

5280 ± 70
$\delta^{13}C = -25.7‰$

ISGS-1038. F 122 (Square 36, Level 25A)

Dispersed carbonized nutshell fragments from a shallow pit overlying the limestone "pavement" in the colluvial fan, near the top of the eroded Middle Archaic stratum (Helton component), 1.5 m below ground surface (Block II). Collected 1979.

ISGS-1036. F 31, Level 9B **5140 ± 70** $\delta^{13}C = -25.4‰$

Dispersed carbonized nutshell fragments (>90% *Carya*) from a pit at the same elevation as a limestone "pavement," marking one surface in the Helton Middle Archaic midden in the colluvial fan 1.2 m below ground surface. Collected 1980.

ISGS-823. F 23, Level 1 **4060 ± 70** $\delta^{13}C = -25.7‰$

Dispersed charcoal (50% wood, 50% nutshell) from a shallow pit extending from buried A horizon soil that contained Late Archaic (Titterington phase) cultural materials, in colluvium 0.4 m below ground surface (Block II). Collected 1980.

Comment (D.L.A.): A flotation sample from the pit contained *Cucurbita* rind.

ISGS-933. F 20 **3920 ± 90** $\delta^{13}C = -25.9‰$

Dispersed charcoal (mostly wood, 10%–15% nutshell, 1% tuber) from a pit extending from buried A horizon that contained Late Archaic (Titterington phase) cultural materials, in colluvium 0.9 m below ground surface (Block II). Collected 1980.

Comment (D.L.A.): F 20 contained *Iva annua* achenes showing morphological evidence of domestication; AMS dating of one achene yielded 4500 ± 500 (NSRL-297) (Conard *et al.* 1984).

ISGS-920. Square 216, Levels 11–12 **2590 ± 70** $\delta^{13}C = -25.3‰$

Dispersed charcoal (80% wood, 20% nutshell) from a cultural deposit 2.0–2.1 m below ground surface in a prehistoric natural levee of the Illinois River, stratigraphically below a Middle Woodland occupation. Collected 1980.

Comment (M.D.W.): A rim of an unidentified sand-tempered vessel was recovered from the stratum; Marion Thick is the only Early Woodland ceramic type recovered from the floodplain.

ISGS-890. Square 196, Level 8B (RC #29) **2530 ± 80** $\delta^{13}C = -26.4‰$

A concentration of wood charcoal representing at least three taxa, 1.8–1.95 m below ground surface in the Illinois River floodplain, from a cultural stratum lacking time-diagnostic artifacts in the small area that was excavated, underlying a Middle Woodland cultural stratum (Block IV). Collected 1980.

ISGS-822. NPH Cr-60, 4.95 m **2060 ± 110** $\delta^{13}C = -26.0‰$

Uncarbonized stems and leaves of trees, grasses, sedges and moss, from a noncultural context in the lower half of a cut-and-fill deposit, 25 m west of the modern course of the Illinois River and 75 m north of the mouth of Napoleon Creek, Pike County, 2 km south-southeast of Valley City (39°41′10″N, 90°38′30″W). Collected 1980 and submitted by T. R. Styles.

ISGS-916. F 45, Levels 1, 1P, 2, 3, 3BP **2000 ± 70** $\delta^{13}C = -25.7‰$

Dispersed charcoal (>90% wood, <10% nutshell) from a pit excavated in the floor of Middle Woodland Structure 1 in the Illinois River floodplain (Block IV). Collected 1980.

Comment (M.D.W.): The pit intersected a more deeply buried cultural deposit, from which ISGS-890 was obtained; minor contamination of F 45 fill with older charcoal cannot be excluded.

ISGS-929. F 42, Levels 1, 2 **1810 ± 70** $\delta^{13}C = -26.5‰$

Dispersed charcoal (>75% bark, <25% wood, <1% *Quercus* shell) from a shallow pit containing only charcoal, in Middle Woodland Structure 1, in the Illinois River floodplain (Block IV). Collected 1980.

Comment (M.D.W.): The predominance of bark in the feature suggests the sample is refuse from a single, specific prehistoric activity.

ISGS-931. Square 237, Level 5 **1880 ± 70** $\delta^{13}C = -25.6‰$

Dispersed charcoal (95% wood, 5% nutshell) from a Middle Woodland trash deposit (Block IV), buried in a small gully in a prehistoric natural levee of the Illinois River, 2.0–2.1 m below ground surface; below ISGS-834. Collected 1980.

ISGS-834. Square 237, Levels 2B, 3A, 3B **1840 ± 70** $\delta^{13}C = -25.7‰$

Dispersed charcoal (90% wood, 10% nutshell) from a Middle Woodland trash dump, 1.8–1.9 m below ground surface, above ISGS-931. Collected 1980.

ISGS-935. Square 73, Levels 8A, 9A **1970 ± 70** $\delta^{13}C = -26.8‰$

Dispersed charcoal (85% wood, 15% nutshell) collected at the base of a shallow gully in a surface Middle Woodland trash deposit extending over a 4 × 6-m area, on the valley-margin hill slope (Block I). Collected 1980.

ISGS-904. Square 73, Levels 3–6; Square 92, Level 2; Square 93, Level 1 **1800 ± 70** $\delta^{13}C = -25.7‰$

Dispersed carbonized nutshell from the trash deposit dated by ISGS-935 (Block I); collected from the unplowed A horizon, within 0.3 m of ground surface. Collected 1980.

Comment (D.L.A.): The date agrees with the expected age. However, a carbonized maize cupule in Square 73, Level 1 yielded a date of 0 ± 300 BP (NSRL-301), indicating some recent contamination of the midden (Conard *et al.* 1984).

General Comment (M.D.W.): For further information, see Wiant and McGimsey (1986) on Woodland components, T. R. Styles (1985) on geology and Wiant, Hajic and Styles (1983) on Archaic occupations.

ISGS-1135. Nutwood Levee and Drainage District, NLC BR11U–56 **9480 ± 130** $\delta^{13}C = -27.0‰$

An uncarbonized piece of *Fraxinus* wood, 11.6 m below the original ground surface, beneath an artificial levee in the Illinois Valley, Jersey County, 4 km northwest of Nutwood (39°06′00″N, 90°35′40″W), from the top of olive gray clay, overlain successively by sand-to-sandy silt, and by silty clay with organics and shell fragments. Collected 1978 by J. Bohnert, U. S. Army Corps of Engineers; submitted by E. R. Hajic and D. L. Asch.

Comment (E.R.H.): This is a minimum age for Holocene downcutting to a relatively low elevation (115.8 m asl). For other dates from the Nutwood Levee project, see Liu, Riley and Coleman (1986b: 121–122); see also Hajic (1987, 1990b).

ISGS-873. Pond, F 7 **2100 ± 70** $\delta^{13}C = -26.0‰$

Dispersed charcoal fragments (80% wood, 20% nutshell) in a pit feature that contained nearly complete Havana Utility and Neteler Crescent pottery vessels. The site is located at the base of a hill slope at the juncture of the Illinois and Spoon River Valleys, Fulton County, 6 km southeast of Lewistown (40°21′00″N, 90°07′00″W). Collected 1961 by J. R. Caldwell; submitted by D. L. Asch and A. M. Cantwell, New York University.

Comment (D.L.A.): The Pond Site is an early Havana tradition (Fulton phase) habitation site (Cantwell 1980). The Dickson Camp site (120 m upslope) and Pond are believed to be sequent occupations, with Pond the later of the two. However, the Pond sample gave the older date. See *Comment* for Dickson Camp (ISGS-872), above.

Scenic Vista series

A Late Archaic (Titterington phase) and Late Woodland habitation site on a blufftop overlooking the Mississippi Valley, Adams County, 1 km northeast of Fall Creek (39°47′00″N, 91°17′50″W). Collected 1980 by H. Hassen; submitted by H. Hassen and D. L. Asch.

ISGS-1422. F 57 **3880 ± 70** $\delta^{13}C = -26.1‰$

Dispersed charcoal (90% wood, 10% nutshell) from a Titterington-component pit, containing a large quantity of chert tool manufacturing debris and several broken and complete Sedalia blades.

ISGS-882. F 42 **1270 ± 70** $\delta^{13}C = -24.8‰$

Dispersed charcoal (85% nutshell, 15% wood, <1% maize) from a Late Woodland refuse pit.

Comments (H.H.): The pit contained a partially smoothed-over, cordmarked ceramic vessel. (D.L.A.): This age, together with others, establishes the presence of maize in west-central Illinois by 1450–1350 BP (Asch & Asch 1985b). See Hassan (1985) and Morgan (1985) for description of the Late Woodland occupation.

Smiling Dan series

A Middle Woodland habitation site, with an earlier minor Middle Archaic occupation and a more recent minor Late Woodland habitation, in Campbell Hollow near the Illinois Valley margin, Scott

County, 7 km south-southwest of Bluffs (39°41′10″N, 90°33′30–40″W). Collected by M. B. Sant; submitted by M. B. Sant, B. D. Stafford and D. L. Asch, except where noted.

ISGS-851. SMD 73–1, 3.20–3.63 m; SMD 73–2, 3.20–3.60 m — **23,380 ± 500**, $\delta^{13}C = -26.6‰$

Uncarbonized wood, bark, seeds and needles from a small tributary valley of Campbell Hollow in Wisconsinan laminated organic silt, directly overlying eroded Illinoian diamiction. Collected 1981 and submitted by E. R. Hajic.

ISGS-989. SMD 18, 4.30–5.40 m; SMD 74, 5.20–5.50 m — **10,460 ± 220**, $\delta^{13}C = -29.4‰$

Non-coniferous wood and twigs (mostly diffuse porous, some carbonized) and herbaceous plant parts, from Unit Ia, overlying conifer wood and needles from the same sedimentological unit. Collected 1980–1981 by E. R. Hajic; submitted by E. R. Hajic and D. L. Asch.

Comments: (D.D.C.): See *Comment* about lithium contamination for ISGS-1000, above. (E.R.H.): This sample dates the lower portion of a silty, valley-filling, slackwater deposit that grades to the Keach School Terrace in the Illinois Valley. See Hajic (1990b).

ISGS-852. Trench D (RC #104) — **8340 ± 130**, $\delta^{13}C = -24.9‰$

Diffuse porous wood charcoal, part of one log; 2.8 m below ground surface, from the base of Campbell Hollow Creek paleochannel fill (base of depositional Unit IIa). Overlying the sample was a very light aceramic scatter of cultural materials. Collected 1979.

Comment (E.R.H.): The sample dates the resumption of valley aggradation in Campbell Hollow after an episode of downcutting.

ISGS-751. Square 956, Level 9 — **6100 ± 140**, $\delta^{13}C = -25.6‰$

Dispersed charcoal fragments (98% nutshell, 2% wood) from the lower portion of colluvial/alluvial lithostratigraphic Unit IIb, 1.5–1.6 m below ground surface, associated with light non-ceramic chert scatter below the Middle Woodland occupation. Collected 1980.

Comment (E.R.H.): Another date from the lower portion of Unit IIb, 6180 ± 100 (Beta-4535) (Stafford & Sant 1985), was obtained from a piece of wood charcoal (*Quercus* subgenus *Erythrobalanus*), from the top of a possible A horizon of a paleosol weakly developed in the colluvium. A thin lithic scatter occurrred in the A horizon.

ISGS-854. Square 39, Levels 17B, 18B, 19B — **2020 ± 70**, $\delta^{13}C = -25.9‰$

Dispersed charcoal fragments (80% wood, 20% nutshell) from the base of a Middle Woodland trash deposit, from gully-filling lithostratigraphic Unit III in a small side-valley to Campbell Creek, 2.2–2.6 m below ground surface. Collected 1980.

ISGS-1094. Squares 15, 40, 402, 417, 900, 901 — **1910 ± 70**, $\delta^{13}C = -25.3‰$

Dispersed carbonized fragments of thick-shelled *Carya* nutshell and thick-shelled Juglandaceae

(*Carya* or *Juglans*), collected across a horizontal distance of 30 m within a Middle Woodland midden, 0.2–0.4 m below ground surface. Collected 1981.

Comment (D.L.A.): Middle Woodland midden east of a site-bisecting gully showed stratification in its nutshell composition, with *Carya*-predominating levels (yielding this sample) underlying *Corylus*-rich levels. This is the oldest Middle-Woodland-associated date at Smiling Dan, except for questionable early ISGS-854.

1790 ± 80

ISGS-1027. F 231, Level 1P $\delta^{13}C = -26.3‰$

Dispersed wood charcoal fragments (70% wood, 30% nutshell) from a shallow Middle Woodland pit. Base leach was omitted. Collected 1981.

Comment (D.L.A.): The charcoal composition of F 231 was characteristic for Middle Woodland pits at Smiling Dan. The pit contained a tobacco seed (*Nicotiana* sp.), 1 of 5 recovered from apparent Middle Woodland contexts at the site. The age determination verifies that tobacco had been introduced to eastern North America by Middle Woodland times.

1780 ± 70

ISGS-841. Trench F (RC #5) $\delta^{13}C = -25.6‰$

Dispersed charcoal fragments (>99% wood) from the base of a Middle Woodland trash deposit, from gully-filling lithostratigraphic Unit III, in a small side-valley to Campbell Creek, 2.0 m below ground surface. Collected 1980.

1700 ± 70

ISGS-958. F 61, Level 1P $\delta^{13}C = -25.6‰$

Dispersed charcoal fragments (10% nutshell, 90% wood, of which 90% is *Sassafras*), from a pit excavated in the top of Level IIb terrace. Collected 1980.

Comment (B.D.S., D.L.A.): Sherds from F 61 included Havana fabric-impressed type (Farnsworth & Koski 1985: 128–131). The date suggests that the pit was used late in the site's Middle Woodland occupation. Charcoal from the pit feature (primarily *Sassafras* wood and several thousand *Phalaris caroliniana* caryopses) differed from the surrounding midden, indicating that the dated charcoal was not redeposited.

1110 ± 70

ISGS-856. F 87, Level 1 $\delta^{13}C = -26.0‰$

Dispersed wood and bark charcoal fragments from the lower 10 cm of a shallow pit excavated into a side slope of the valley; the pit was discovered at the base of the surface A horizon. Collected 1981.

Comments (B.D.S.): F 87, one pit in a small Late Woodland pit cluster, lacked culturally diagnostic artifacts. The date establishes its Late Woodland cultural affiliation. (D.L.A.): Late Woodland pits at the site contained little nutshell, which suggests that the dated charcoal from them was not redeposited from the nutshell-rich Middle Woodland midden.

1100 ± 70

ISGS-1207. F 115, Level 3 $\delta^{13}C = -25.5‰$

Dispersed carbonized wood and bark fragments from a pit containing grit-tempered, smoothed-over-cordmarked Late Woodland pottery decorated with a punctate band around an angular shoulder (Bauer Branch ceramic series). Base leach was omitted. Collected 1981.

Comment (B.D.S.): F 115 was in the pit cluster containing F 87.

ISGS-843. F 28, Level 3P — **1050 ± 70**, $\delta^{13}C = -25.8‰$

Dispersed charcoal fragments (99% wood, 1% tuber) from a trash concentration at the base of a Late Woodland pit. Collected 1980.

General Comment (B.D.S.): The site report (Stafford & Sant 1985) describes contexts for other Middle Woodland ^{14}C dates from the site: 1830 ± 50 BP (Beta-4534), 1805 ± 95 BP (Beta–4980) and 1630 ± 80 BP (Beta-4981).

Titus series

A stratified multicomponent Early Archaic, Terminal Archaic and Late Woodland habitation site on a colluvial fan near the mouth of Macoupin Creek Valley, Greene County, 7 km northeast of East Hardin (39°11′30″N, 90°32′30″W). Collected 1973 by S. Noble; submitted by D. L. Asch.

ISGS-826. Test Square 1, Level 10 — **3240 ± 70**, $\delta^{13}C = -25.5‰$

Dispersed charcoal (75% nutshell, 25% wood) 1.4–1.5 m below ground surface and 0.8–0.9 m below the top of cultural Horizon 2.

ISGS-990. Test Square 1, Levels 5–6 — **2860 ± 80**, $\delta^{13}C = -25.6‰$

Dispersed charcoal (85% nutshell, 15% wood) 0.65–0.85 m below ground surface, in Horizon 2 near its eroded upper surface.

General Comment (D.L.A.): Cultural Horizon 2 is a terminal Archaic Kampsville phase midden (Prairie Lake culture), perhaps with minor occupation occurring as early as the Titterington phase (Farnsworth & Asch 1986: 344). The date provides evidence of stratification within Horizon 2. Early Archaic/early Holocene dates from Titus were reported in Liu, Riley and Coleman (1986a: 79–80).

Vasconellos Sand Pit series

From the Illinois Valley, Scott County, 6 km east of Florence (39°38′00″N, 90°32′20″W). Collected by D. S. Leigh; submitted by E. R. Hajic, D. S. Leigh and D. L. Asch.

ISGS-1169. Vascon 1A, B, D — **10,900 ± 80**, $\delta^{13}C = -28.7‰$

Uncarbonized wood (the microscopic structure was mostly collapsed, but some fragments were recognizable as diffuse porous); from 8 to 10-cm-thick soil O horizon containing twigs and peat developed in a depression on a Bath Terrace remnant(?), below eolian sand. Collected 1983.

ISGS-1277. Vascon 2 — **11,070 ± 190**, $\delta^{13}C = -26.4‰$

Uncarbonized pieces of *Fraxinus* wood underlying the soil O horizon from which ISGS-1169 was collected, in fine sandy loam. Collected 1984.

General Comment (E.R.H.): See Hajic (1990b).

REFERENCES

Asch, D. L. and Asch, N. B. 1985a Prehistoric plant cultivation in west-central Illinois. *In* Ford, R. I., ed., Prehistoric food production in North America. *Museum of Anthropology, University of Michigan Anthropological Papers* 75: 149–203.

Asch, N. B. and Asch, D. L. 1985b Archeobotany. *In* McGimsey, C. R. and Conner, M. D., eds., Deer Track, a Late Woodland village in the Mississippi Valley. *Center for American Archeology, Technical Reports* 1: 44–117.

Atwell, K. A. and Conner, M. D. 1991 The Kuhlman mound group and late Woodland mortuary behavior in the Mississippi River Valley of west-central Illinois. *Center for American Archeology, Research Series* 9.

Brown, J. A. and Vierra, R. K. 1983 What happened in the Middle Archaic? Introduction to an ecological approach to Koster site archaeology. *In* Phillips, J. L. and Brown, J. A., eds., *Archaic Hunters and Gatherers in the American Midwest.* New York, Academic Press: 165–195.

Butzer, K. W. 1977 Geomorphology of the lower Illinois Valley as a spatial-temporal context for the Koster Archaic site. *Illinois State Museum Reports of Investigations* 34: 60 p.

Cantwell, A-M. 1980 Dickson Camp and Pond: two early Havana tradition sites in the central Illinois Valley. *Illinois State Museum Reports of Investigations* 36: 175 p.

Coleman, D. D. 1973 Illinois State Geological Survey radiocarbon dates IV. *Radiocarbon* 15(1): 75–85.

_____1974 Illinois State Geological Survey radiocarbon dates V. *Radiocarbon* 16(1): 105–117.

Coleman, D. D. and Liu, C. L. 1975 Illinois State Geological Survey radiocarbon dates VI. *Radiocarbon* 17(2): 160–173.

Conard, N., Asch, D. L., Asch, N. B., Elmore, D., Gove, H., Rubin, M., Brown, J. A., Wiant, M. D., Farnsworth, K. B. and Cook, T. G. 1984 Accelerator radiocarbon dating of evidence for prehistoric horticulture in Illinois. *Nature* 308: 443–446.

Conner, M. D. (ms.) 1984 Population structure and biological variation in the Late Woodland of west-central Illinois. PhD dissertation, Department of Anthropology, University of Chicago.

_____1986 Cypress Land, a Late Archaic/Early Woodland site in the lower Illinois River floodplain. *Center for American Archeology, Technical Reports* 2: 79 p.

Esarey, D. 1988 The Liverpool Lake site: Results of archaeological monitoring at 11Mn63, Mason County, Illinois. Dickson Mounds Museum, submitted to Chautauqua National Wildlife Refuge and U. S. Fish and Wildlife Service, Region 3, 76 p.

Farnsworth, K. B. and Asch, D. L. 1986 Early Woodland chronology, artifact styles, and settlement distribution in the lower Illinois Valley region. *In* Farnsworth, K. B. and Emerson, T. E., eds., Early Woodland Archeology. *Center for American Archeology, Kampsville, Seminars in Archeology* 2: 326–457.

Farnsworth, K. B. and Koski, A. L. 1985 Massey and Archie: A study of two Hopewellian homesteads in the western Illinois uplands. *Center for American Archeology* 3: 264 p.

Hajic, E. R. 1985 Terminal Pleistocene events in the Mississippi Valley near St. Louis as inferred from Illinois Valley geology. *In* Lively, R. S., ed., Pleistocene geology and evolution of the Upper Mississippi Valley. *Abstracts and Field Trip Guide: Minnesota Geological Survey*: 49–52.

_____1987 Geoenvironmental context for archeological sites in the lower Illinois River Valley. *U. S. Army Corps of Engineers, St. Louis District Cultural Resource Management Report*: 34.

_____1990a Koster site archeology I: Stratigraphy and landscape evolution. *Center for American Archeology, Research Series* 8.

_____(ms.) 1990b Late Pleistocene and Holocene landscape evolution, depositiional subsystems and stratigraphy in the lower Illinois River Valley and adjacent Central Mississippi River Balley. Ph.D. dissertation, Department of Geology, University of Illinois, Urbana-Champaign, University microfilms, Ann Arbor, Michigan.

Harn, A. D. (ms.) 1986 The Eveland site: Inroad to Spoon River Mississippian society. Paper presented at the 51st Annual Meeting of the Society for American Archaeology, New Orleans, April 16–19.

Hassen, H. 1985 Late Woodland diversity in the Fall Creek locality, Adams County, Illinois. *Wisconsin Archeologist* 66: 282–291.

Liu, C. L., Riley, K. M. and Coleman, D. D. 1986a Illinois State Geological Survey radiocarbon dates VIII. *Radiocarbon* 28(1): 78–109.

_____1986b Illinois State Geological Survey radiocarbon dates IX. *Radiocarbon* 28(1): 110–133.

McGimsey, C. R. and Conner, M. D., eds., 1985 Deer Track, a Late Woodland village in the Mississippi Valley. *Center for American Archeology, Technical Reports* 1: 134 p.

Morgan, D. T. 1985 Late Woodland ceramics from the Fall Creek locality, Adams County, Illinois. *Wisconsin Archeologist* 66: 265–281.

Stafford, B. D. and Sant, M. B., eds., 1985 Smiling Dan: Structure and function at a Middle Woodland settlement in the Illinois Valley. *Center for American Archeology, Research Series* 2: 487 p.

Stafford, C. R., ed., 1985 The Campbell Hollow Archaic occupations, a study of intrasite spatial structure in the lower Illinois Valley. *Center for American Archeology, Research Series* 4: 276 p.

Struever, S. 1968 Flotation techniques for the recovery of small-scale archaeological remains. *American Antiquity* 33: 353–362.

Styles, B. W. 1981 Faunal exploitation and resource selection: early Late Woodland subsistence in the lower Illinois Valley. *Northwestern University Archeology Program, Science Paper* 3: 312 p.

Styles, T. R. 1985 Holocene and Late Pleistocene geology of the Napoleon Hollow site in the lower Illinois River Valley. *Center for American Archeology, Research Series* 5: 146 p.

Wiant, M. D. 1983 Deflocculants and flotation: considerations leading to a low–cost technique to process high clay content samples. *American Archaeology* 3: 206–209.

Wiant, M. D., Hajic, E. R. and Styles, T. R. 1983 Napoleon Hollow and Koster site stratigraphy: implications for Holocene landscape evolution and studies of Archaic period settlement patterns in the lower Illinois River valley. *In* Phillips, J. L. and Brown, J. A., eds., *Archaic Hunters and Gatherers in the American Midwest.* New York, Academic Press: 147–164.

Wiant, M. D. and McGimsey, C. R., eds., 1986 Woodland period occupations of the Napoleon Hollow site in the lower Illinois Valley. *Center for American Archeology, Research Series* 6: 612 p.

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DEPARTMENT OF EARTH SCIENCES AT THE UNIVERSITY OF ROME RADIOCARBON DATES I

GILBERTO CALDERONI and VINCENZO PETRONE

Department of Earth Sciences, University of Rome I "La Sapienza," Piazzale Aldo Moro 5
00100 Rome, Italy

INTRODUCTION

We report here, in part, dates measured on samples from Italy since the construction of a new ^{14}C lab in 1990 for research in the fields of geology, paleomorphology and the biogeochemical cycle of carbon. We use liquid scintillation counting (LSC), following sample conversion to benzene through the four classical chemical steps: 1) combustion or hydrolysis to CO_2; 2) production of Li_2C_2; 3) hydrolysis to C_2H_2; 4) trimerization of acetylene to C_6H_6 with specific catalysts. The vacuum line for benzene synthesis has been designed following a comparative review of the literature (Tamers 1960; Noakes *et al.* 1963; Scharpenseel & Pietig 1970; Harkness & Wilson 1973; Polach, Gower & Fraser 1972; Gupta & Polach 1985), and the valuable suggestions of many colleagues from well-established labs abroad. The compact vacuum line is mostly modular with "O"-ring-joined components, and is equipped with greaseless stopcocks. We use commercial two-stage rotary pumps, pressure transducers and gauges; an electrovalve coupled with a pressure control unit supplies the purified oxygen for sample combustion while holding constant, just higher than 1 atm, the gas pressure inside the combustion tube.

The dates were measured by LSC of benzene in commercial low-K, 7-ml slim-line vials, previously checked for comparable background, in a Packard 2260 XL counter. The selection of fluor(s) suitable to operate the counter with the low-level option may be critical; a secondary wave shifter fluor is needed to achieve acceptable efficiency (Noakes & Valenta 1989). We overcame initial problems by using a scintillation cocktail made up by butyl - PBD and bis - MSB (13 and 1.3 mg $\cdot$ ml^{-1} benzene, respectively). Our results agreed with the data of others (Cook, Harkness & Anderson 1989; Cook *et al.* 1990) in that the cocktail is both fairly stable and resistant against chemical quenching with high counting efficiency. For the 3-g counting geometry, efficiency is better than 72% and background averages 1.400 ± 0.021 cpm.

Samples were counted for a minimum of 2000 min in 25-min intervals, in batches containing two background and two modern samples. Quenching is monitored with the parameter, t-SIE, supplied as a part of the software package by the counter manufacturer. Data from the counter, collected on-line onto a floppy disk, are loaded to a custom-made software program for statistical and age calculation (Calderoni & Venanzi 1989).

Charcoal and wood samples were boiled with 3 N HCl followed by rinsing with water and, when tested positive for humic matter, the latter was extracted with 0.1 N NaOH. Paleosol pretreatment included hydrolysis at 100°C with 6 N HCl and, when possible, extraction with 1 N NaOH of the humic fraction of the bulk humic matter.

We report dates according to the suggestions of Stuiver and Polach (1977), *i.e.*, in years BP, based on the conventional Libby half-life for ^{14}C of 5568 years, and where necessary, corrected for isotopic fractionation ($\delta^{13}C$ values are reported as per mil deviation from the PDB standard). Oxalic Acid I and ANU Sucrose are the modern reference standards; benzene prepared from industrial coke was used as background, and to dilute smaller samples to the selected geometry. The quoted errors, ± 1 σ confidence level, include the standard deviations of count rates for unknown, background and modern samples. Also included are the known laboratory uncertainties contributed by benzene dilution and weighing and $\delta^{13}C$ measurement.

The procedures we adopted for quality assessment and control focus on β-acitivity measurement, accuracy and reproducibility throughout the dating process. We check performance of activity measurement monthly by running background, Oxalic Acid I and an internal-test solution prepared by diluting labeled benzene (400 dpm ml^{-1}, obtained from SURRC, Glasgow). Our criterion for reliable short- and long-term system performance is linear (horizontal) count rates *vs.* time. Deviations from linearity alert of system malfunction. We monitor the analytical precision and accuracy through the global dating process by running secondary standards and an internal tertiary standard three times a year, and after repair and/or modification of the benzene synthesis line. Table 1 lists the results for the reference materials.

TABLE 1. Results for Replicate Measurements of Secondary and Tertiary Standards

Material	Percent of Modern (pMC)
Sucrose ANU	150.91 ± 1.04; 149.92 ± 1.00; 150.55 ± 1.02; 149.38 ± 1.06; 150.13 ± 1.05
Cellulose IAEA	130.96 ± 1.03; 129.85 ± 1.08; 130.68 ± 1.05;
Commercial charcoal*	99.02 ± 0.79; 99.74 ± 0.81; 98.47 ± 0.85

*Commercial, pre-bomb (1948–1950) charcoal is used in Rome as the "in house" tertiary standard since 1964 (Alessio, Bella & Cortesi 1984).

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GEOLOGICAL SAMPLES

Mt. Calvario series

Samples are from a two-paleosol (PAs) suite of Late Quaternary age, overlying Cretaceous micritic limestones, interbedded with polygenetic, tectonic breccia, and underlying a gravel unit. The site was exposed during quarrying on the south slope of Mt. Calvario (1743 m asl), Sangro River valley, central Apennines, 40 km east of Aquila, Abruzzi region (42°52′13″N, 14°03′16″E). The PAs record two phases of slope stability, both long enough for pedogenesis. After its formation, the lowermost PA experienced many neotectonic events, the last one being responsible for its burial. This is documented by an overall subvertical fault, measuring over 1 m of downthrow. The date for the uppermost, undisturbed PA provides a minimum age for a significant paleoseismological event that occurred during the Holocene (Calderoni *et al.* 1990). The PAs samples were collected and submitted August 1990 by G. Calderoni and L. Serva (ENEA-DISP, Rome).

38,500 ± 2000

Rome-125. Mt. Calvario 1 $\delta^{13}C = -27.3‰$

Humic acids and humin fractions from sandy silt (2 mm–2 μ) of the lowermost PA, *ca.* 50 cm thick, outcropping 10 m above the quarry ground level.

Rome-126. Mt. Calvario 1 **39,800 ± 2200**
$\delta^{13}C = -27.0‰$

Humic acids and humin fractions from silty clay (<2 μ) of the lowermost PA. Concordance with Rome-125, indicating that the apparent age of humic matter is unaffected by the PA particle size, could also mean that primitive organic carbon redistributed during pedogenesis.

Rome-127. Mt. Calvario 2 **4650 ± 75**
$\delta^{13}C = -27.5‰$

Humic acids and humin fractions from the bulk of the uppermost PA, 30 cm thick, are probably likely a relict of B horizons of an andosol, exposed 12 m above the quarry ground level.

General Comment: The PA samples were previously hydrolyzed for 4 h at 100°C with 18% HCl for complete removal of both carbonate bedrock fragments and fulvic acids. Ages are consistent with the stratigraphy. The organic carbon content (1.72, 2.05 and 4.27%: Rome-125, -126, -127, respectively) decreases antithetically with age and particle size. By contrast, the C/N ratio for all the humic matter in the PAs is almost constant (mean = 8.3 ± 1.0), suggesting common pathways of pedogenesis and diagenesis.

Mounts of the Laga Chain series

The southern flank of the Laga Mountain chain in the central Apennines was selected for neotectonic and paleoseismological study because of historical accounts of seismic events and evidence of active tectonics. Dislocation features, *e.g.*, dissected alluvial terraces of the Tronto River and late Würmian fans of Campotosto, are particularly apparent at the piedmont belt of the chain (Bachetti *et al.* 1990). Recent road construction at the eastern edge of Piano di Montereale, Aterno River valley, Aquila, central Apennines (42°34′19″N, 13°22′35″E) exposed a sedimentary sequence. Here, a fluviatile, swampy layer yielded brown wood fragments, partly replaced by pyrite. Samples were collected and submitted 1989 by A. M. Blumetti, Department of Earth Sciences, University of Camerino.

Rome-128. Mounts of the Laga **39,500 ± 2700**

Heavily pyritized small wood fragments.

Comment: According to field data, the dated level rests on a small depression formed during the tilting of a section of the piedmont belt. Wood pyritization probably occurred during severe anoxic conditions that developed in the former basin of sedimentation. This resulted from significant, tectonically induced geomorphological changes that affected the drainage basin.

Middle Cesano River Basin series

Five wood samples from terraced alluvial sediments exposed in the middle valley of the Cesano River were dated as part of continuing research to establish a time scale for geomorphological variations of the central Apennines during the Late Quaternary. This reach of the Apennines has a unique feature, in that mountainous chains and basins are northwest-southeast-directed (Apennine direction), whereas most drainage systems flow northeastwards, probably owing to anti-Apennine trending faults that represent a preferential path of incision. Following tectonic displacements, the Cesano River eroded and accumulated sediments from the resulting catchment area. This was recorded by widespread fluvial terrace deposits along the main valley. Four groups of terraces have been defined according to elevation from the valley floor (Lipparini 1938; Selli 1954; Nesci &

Savelli 1990), from the older T1 (top) to the younger T4 (base). Preliminary dating of samples from nearby sites revealed that 4th- and, in part, 3rd-order terraces formed from the Late Pleistocene through the Holocene, although changes in individual streams effect significant variations in the terraces (Alessio *et al.* 1987). Samples originated from the walls of two clay quarries at St. Michele al Fiume (12°59′43″E, 43°39′37″N) and St. Lorenzo in Campo (12°56′43′E, 43°36′06″N), located in the Marchean Apennines close to the north bank of the middle Cesano River, at *ca.* 15 and 25 km, respectively, upstream from the sea coast. Collected and submitted 1990 by O. Nesci and D. Savelli, Institute of Geology, University of Urbino.

Rome-108. St. Michele al Fiume SN#1 **35,600 ± 1800**

Well-preserved dark wood from gray-blue, clayey-silty sand at the base of the section, underlying braided-stream sediments and overlying the Pliocene-age clayey-marl base.

Rome-109. St. Michele al Fiume SN#2 **37,300 ± 2000**

Rome-110. St. Michele al Fiume SN#4 **32,500 ± 1200**

Well-preserved brown wood samples from a fine-grained layer, underlying braided-stream sediments with festoon-like cross-stratification.

Rome-111. St. Lorenzo in Campo SN#5 **31,700 ± 1000**

Rome-112. St. Lorenzo in Campo SN#6 **37,300 ± 2200**

This section exposes the middle-to-upper part of 3rd-order terrace alluvium. Well-preserved, dark wood samples from small clayey-silty-sandy lenses contained in the lowermost pebbly layer.

General Comment: Samples from both sites are associated with a late phase of 3rd-order terrace fluvial deposits. Features include strip-shape, overall southwest-northeast trending and a thickness averaging 30 m. At present, the terraced suite outcrops from 5 to *ca.* 15 m above the talweg of the Cesano River Valley. Although the samples were partly *in-situ* trees and partly flooded tree branches, the ages indicate that the two dated sediment PAs are almost syngenetic and formed during the Würmian late glacial stage, *viz*, Pre-Bølling-Mstno.

Esino River valley series

This series contains the first dates for 3rd-order alluvial terraces of the middle Esino River valley, Matelica, central Apennine chain. Alluvial sediments, deposited here during Esino River floods, overlie the Miocene sandstone base of the Camerino basin, and their relationships with both 2nd- and 4th-order terraced sediments are recognizable. Samples originated from five exposures close to the river banks, and are representative of a significant reach of the valley. Samples were collected and submitted 1990 by M. Coltorti, Department of Earth Sciences, University of Camerino.

Rome-139. Esino River valley, Section 22 **31,800 ± 1100**

Scattered fragments of well-preserved charcoal from a sandy-silty layer at Casa Falceto IV (43°16′45″N, 12°59′57″E).

Rome-140. Esino River valley, Section 20 **41,000 ± 4000**

A dark macrofragment of wood from a clayey layer.

Rome-141. Esino River valley, Section 20 **>41,000**

Fragments of wood from a sandy-silty layer, 1 m below Rome-140, from Casa Felceto I (43°16′37″N, 12°59′46″E).

Rome-142. Esino River valley, Section 23 **30,200 ± 900**

Fragments of tree roots and peat from a sandy layer at Fosso Pagliano I (43°17′00″N, 12°59′39″E).

Rome-143. Esino River valley, Section 30 **32,700 ± 1200**

A macrofragment of dark, well-preserved wood from the lowermost clayey level at Casa Incrocca II (43°17′51″N, 12°59′08″E).

Rome-144. Esino River valley, Section 39 **23,500 ± 400**

Small charcoal fragments scattered through a lens.

Rome-145. Esino River valley, Section 39 **32,500 ± 1200**

Wood fragments 1.5 m below Rome-144 from the basal clayey layer at Case Pezza-Ansuini (43°19′31″N, 12°59′36″E).

General Comment: The dates indicate that 3rd-order terraces formed well before the Holocene in the Esino River valley and the northernmost valleys of the central Apennines, so far investigated. The origin of the terraces, probably triggered by dramatic neotectonic events and/or climatic changes, involved recurrent cycles. The beginning of such a catastrophic phase, however, is beyond the limits of ^{14}C dating.

Borgiano Deposit series

A sedimentary sequence consisting of intercalations of both slope-waste deposits and alluvial fan sediments was exposed during road construction near Borgiano Lake, the middle Chienti River valley, Marchean Apennines, central Italy (43°07′50″N, 13°12′00″E). The area is very interesting, in that recurrent neotectonic events badly fractured the carbonate bedrock, thus increasing both erosion and landslides. The deposit (Calderoni *et al.* 1991) is on 3rd-order terraced sediments (see Middle Cesano River valley series, above) and shows stratigraphic relationships with 4th-order Holocene alluvium. The sampled section shows numerous horizons of Rendzinic soil, intercalated with slope-waste debris and alluvial fan sediments at the contact with the basal slope and in the outer part of the deposit, respectively. Following stratigraphic analysis, the paleosol horizons were assigned to two suites, upper and lower, separated by significant lateral variations. The samples were collected and submitted 1989 by M. Coltorti, G. Pambianchi and F. Dramis, Department of Earth Sciences, University of Camerino.

Rome-129. Borgiano Deposit 1 **1620 ± 60**

Humic acids from the topmost humified layer of the upper paleosol suite. $\delta^{13}C = -28.1‰$

1700 ± 65

Rome-130. Borgiano Deposit 2 $\delta^{13}C = -27.5‰$

Humic acids from the topmost humified layer of the upper paleosol suite, 50 m apart from Rome-129.

Rome-131. Borgiano Deposit 3 **2270 ± 70**
$\delta^{13}C = -25.5‰$

Fragments of well-preserved charcoal, associated with pottery, from a fireplace found in a shelter filled by gravels, underlying Rome-130.

Rome-132. Borgiano Deposit 4 **4020 ± 70**
$\delta^{13}C = -27.2‰$

Humic acids from the humified layer at the bottom of the upper paleosol suite.

Rome-133. Borgiano Deposit 5 **5870 ± 70**

Humic acids from the humified layer overlying the lower paleosol suite. $\delta^{13}C = -27.8‰$

Rome-134. Borgiano Deposit 6 **8100 ± 80**
$\delta^{13}C = -27.3‰$

Humic acids from the humified layer at the bottom of the lower paleosol suite, close to the base of the section.

General Comment: Dates on humic acids yield minimum ages for significant phases of slope stability (lasting long enough for pedogenesis) throughout most of the Holocene, including the arrival of humans to the area.

Orbetello Lagoon series

As part of research on the origin, fate and distribution of organic matter input in a lagoonal environment, four samples of basal sediments from Orbetello Lagoon (central Italy, Thyrrenian coast, Tuscany) were collected. The lagoon is shallow (1.5 m–30 cm), 27 km^2 wide and overlies part of a Miocene tectonic depression bordered seawards by sand banks; the two narrow channels communicating with the sea do not allow enough water turnover for preventing eutrophication. The study area was selected for little pollution, lack of significant continental input from streams and the existence of comprehensive geological, morphological and environmental records (Lazzarotto, Mazzanti & Mazzoncini 1964; Bartolini *et al.* 1977; Brambati *et al.* 1979). The samples were collected and submitted 1990 by M. Angeloni and R. Gragnani, ENEA-Casaccia, Rome.

Rome-135. Orbetello 1 **$\Delta^{14}C = -95.91 \pm 7.63‰$**
$\delta^{13}C = -18.3‰$

HCl-refractory organic matter from Station C_3 (42°26′08″N, 11°12′08″E), facing the village of Orbetello, *ca.* 3 km from land.

Rome-136. Orbetello 2 **$\Delta^{14}C = -90.63 \pm 7.72‰$**
$\delta^{13}C = -19.2‰$

HCl-refractory organic matter from Station C_4 (42°25′40″N, 11°16′26″E), at the southern lagoon apex, *ca.* 500 m from land.

Rome-137. Orbetello 3 **$\Delta^{14}C = +64.83 \pm 8.52‰$**
$\delta^{13}C = -18.5‰$

HCl-refractory organic matter from Station C_5 (42°26′49″N, 11°14′24″E), at the middle of the lagoon, *ca.* 500 m from land.

Rome-138. Orbetello 4 **$\Delta^{14}C$ = −51.27 ± 7.81‰**
$\delta^{13}C$ = −18.6‰

HCl-refractory organic matter from Station C_6 (42°25′40″N, 11°11′55″E), at the western lagoon edge, *ca.* 5 km from land.

General Comment: We ran measurements on the fulvic acids- and proteinaceous-compound-free organic matter escaped to the intensive acidic hydrolysis performed for removing both carbonates and the most geochemically mobile organic compounds. The negative $\Delta^{14}C$ values for Rome-135, -136 and -138 reveal a significant mean residence time for the surficial, most stable organic matter, hardly predictable with the available data on enhanced lagoon eutrophication. Sample R-137 yields a post-bomb $\Delta^{14}C$ level approaching, to some extent, that of atmospheric $^{14}CO_2$ at the sampling year, thus suggesting a strikingly fast production through local biological pathways. This involves a marked drop in the $\delta^{13}C$ value from *ca.* −8‰ (mean for atmospheric CO_2) to the measured value, −18.5‰. Values for $^{13}C/^{12}C$ ratio support a prevailing marine origin for organic input; however, a secondary contribution from continental higher plants is suggested by the distribution pattern of *n* - alkanes in the dated organic matter (Monti 1991).

Lago Lungo series

Lago Lungo, *ca.* 7 km north of Rieti, Latium, central Italy (42°28′12″N, 12°40′17″E), presently a small pond, was an active sedimentation basin for alluvium from its catchment area during the Late Quaternary. In 1989, the sedimentary sequence was drilled to 81.50 m depth to study climatic change through pollen analysis and to establish a time scale for the Pleistocene-Holocene transition. The samples were collected and submitted 1990 by R. Pezzarossa, SIAGI Spa, Rome.

Rome-146. Lago Lungo 1 **8050 ± 100**

Small fragments of dark wood, 26.30–26.40 m deep in core. *$\delta^{13}C$ = −24.2‰*

Rome-147. Lago Lungo 2 **>41,000**

Fragments of well-preserved brown wood, 36.10–36.20 m deep in core. *$\delta^{13}C$ = −23.7‰*

General Comment: The dates were measured for preliminary evaluation of age and sedimentation rate. While sedimentological, geochemical and pollen analyses are underway, the age of Rome-146 is a significant chronostratigraphic constraint on the beginning of the Holocene.

Aeolian Archipelago series

The Aeolian Archipelago, consisting of seven islands, lies northwest of the northeast apex of Sicily (southern Tyrrhenian Sea), and is an important active volcanic arc in the Mediterranean Sea (Barberi *et al.* 1974; Keller 1979). The samples were dated as part of an ongoing study of tephrochronology for the recurrent explosive eruptions from the volcanic districts in central and southern Italy through the Late Quaternary.

Rome-148. Filicudi Island **>41,000**

Well-preserved bits of charcoal from a *ca.* 15-m-thick tephra sequence, containing the last pyroclastic deposits that blanketed the island, exposed close to the harbor of Filicudi Island (38°33′28″N, 14°34′49″E). Samples were contained in a layer of muddy, yellowish ash flow, in about the middle of the suite, underlying several ash and pumiceous layers. Their age suggests volcanic activity far older than that responsible for the "brown tuffs" spread throughout most of the Aeolian Islands (Calderoni, La Volpe and Lo Sito 1991). The samples were collected and submitted 1990 by A. Manetti, Department of Earth Sciences, University of Firenze.

Rome-149. Volcano Island **7680 ± 100**

Scattered charcoal fragments from a tephra layer exposed at Volcano Piano (38°23′10″N, 14°58′35″E). The date is important because it may reveal that "brown tuff" emplacement (Calderoni, La Volpe and Lo Sito 1991) lasted longer than previously believed. The samples were collected and submitted 1989 by R. Lo Sito, Department Geomineralogico, University of Bari.

Miscellaneous samples

Rome-150. Sorrento **>41,000**

Peaty, dark clayey sediment containing almost completely humified wood fragments, 14.70–14.90 m deep from a continuous core drilled 4 km west of Sorrento, Campania, southern Italy (40°37′32″N, 14°21′30″E). The sample underlay weathered tephra and lava fragments that can be firmly attributed to known phases of nearby volcanic areas. The sample was collected 1991 by S. Palomba, Centro Geologica Tecnica, Sorrento and submitted by D. Stanzione, Department of Earth Sciences, University of Napoli.

Rome-151. La Piantata **3000 ± 70**

Small, well-preserved fragments of tree branches partly charred at 12 m depth in a core from continuous drilling of a Middle Pleistocene lacustrine deposit at La Piantata, Urbino, central Apennines (43°44′22″N, 12°37′42″E). The young age reflects some recent reworking of the sediment suite. The sample was collected and submitted 1991 by F. Veneri, Institute of Mineralogy and Petrology, University of Urbino.

References

Alessio, M., Allegri, L., Azzi, C., Calderoni, G., Cortesi, C., Improta, S., Nesci, O., Petrone, V. and Savelli, D. 1987 Successioni alluvionali terrazzate nel medio bacino del Metauro (Appennino Marchigiano – Datazione con il ^{14}C. *Geografia Fisica Dinamica Quaternaria* 10: 307–312.

Alessio, M., Bella, F. and Cortesi, C. 1984 University of Rome carbon-14 dates II. *Radiocarbon 6*: 77–90.

Bachetti, C., Blumetti, A. M., Calderoni, G. and Ridolfi, M. 1990 Attività neotettonica nel settore meridionale dei Monti della Laga. *Rendiconti della Societa Geologica Italiana* 13: 9–16.

Barberi, F., Innocenti, F., Ferrara, G., Keller, J. and Villari, L. 1974 Evolution of eolian arc volcanism (Southern Tyrrhenian Sea). *Earth and Planetary Science Letters* 21: 269–276.

Bartolini, C., Corda, L., D'Alessandro, L., La Monica, G. B. and Regini, E. 1977 Studi di geomorfologia costiera: III – Il tombolo di Feniglia. *Bolletino della Societa Geologica Italiana* 96: 117–157.

Brambati, A., Fanzutti, G. P., Marocco, R., Panella, S. and Magazzù, G. 1979 Caratteristiche sedimentologiche ed idrologiche della laguna di Orbetello (Toscana). *Archivo Oceanografia e Limnologia* 19(3): 179–122.

Calderoni, G., Coltorti, M., Consoli, M., Farabollini, P., Dramis, F., Pambianchi, G. and Percossi, E., in press, Degradazione dei versanti e sedimentazione nei pressi di Borgiano (Appennino Marchigiano) nell'Olocene recente. *Memoire della Societa Geologica Italiana.*

Calderoni, G., La Volpe, L. and Lo Sito, R., in press, Stratigraphy of the brown tuff deposits from the island of Lipari (Aeolian Islands, southern Italy). *Journal of Volcanology and Geothermal Research.*

Calderoni, G., Lorenzoni, P., Ortolani, F., Pagliuca, S. and Serva, L. 1990 Paleoseismological evidence at Rivisondoli, Central Apennines, Italy. *Rendiconti della Societa Geologica Italiana* 13: 27–32.

Calderoni, G. and Venanzi, G. (ms.) 1989 Implementation of a software package for the statistical treatment of counting data from a β-spectrometer and calculation of conventional radiocarbon ages. *Internal Report.* Department of Earth Sciences, University of Rome.

Cook, G. T., Harkness, D. D. and Anderson, R. 1989 Performance of the Packard 2000CA/XL and 2250CA/XL liquid scintillation counters for ^{14}C dating. *In* Long, A. and Kra, R. S., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 352–358.

Cook, G. T., Naysmith, P., Anderson, R. and Harkness, D. D. 1990 Performance optimisation of the Packard 2000CA/XL liquid scintillation counter for ^{14}C dating. *Nuclear Geophysics* 4(2): 241–245.

Gupta, S. K. and Polach, H. A. 1985 Radiocarbon dating practice at ANU: Handbook. Radiocarbon Laboratory, Research School of Pacific Studies, ANU, Canberra: 173.

Harkness, D. D. and Wilson, H. W. 1973 Some application in radiocarbon measurements at the Scottish research reactor centre. *In* Rafter, T. A. and Grant-Taylor, T., eds., *Proceedings of the 8th International* ^{14}*C Conference*. Wellington, Royal Society of New Zealand 1: 209–219.

Keller, J. 1979 Mediterranean island arcs. *In* Thorpe, R. S., ed., *Organic Andesites and Related Rocks*. New York, John Wiley & Sons: 237.

Lazzarotto, A., Mazzanti, R. and Mazzoncini, F. 1964 Geologia del Promontorio dell'Argentario (Grosseto) e del Promontorio del Franco (Isola del Giglio-Grosseto). *Bolletino della Societa Geologica Italiana* 83(2): 1–124.

Lipparini, T. 1938 I terrazzi fluviali delle Marche. *Giornale di Geologia* 13:5–22.

Monti, A. (ms) 1991 Origine, contenuto, distribuzione e turnover di C, N e P nei sedimenti della laguna di Orbetello. Thesis, Department of Earth Sciences, University of Rome, Italy.

Nesci, O. and Savelli, D., in press, Valley terraces in the northern Marche Apennines, Central Italy: cycling deposition and erosion. *Giornale di Geologia*: 52–53.

Noakes, J. E., Isbell, A. F., Stipp, J. J. and Hood, D. W. 1963 Benzene synthesis by low temperature catalysis for radiocarbon dating. *Geochimica et Cosmochimica Acta* 27(7): 797–804.

Noakes, J. E. and Valenta, R. J. 1989 Low background liquid scintillation counting using an active sample holder and pulse discrimination electronics. *In* Long, A. and Kra, R. S., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 332–341.

Polach, H. A., Gower, J. and Fraser, I. 1972 Synthesis of high purity benzene for radiocarbon dating. *In* Rafter, T. A. and Grant-Taylor, T., eds., *Proceedings of the 8th International* ^{14}*C Conference*. Wellington, Royal Society of New Zealand 1: 144–157.

Scharpenseel, H. W. and Pietig, F. 1970 Determination of age by liquid scintillation spectrometry: Simplified benzene synthesis also from small CO_2 quantities. *Atompraxis* 16(3): 1–2.

Selli, R. 1954 Il bacino del Metauro. *Giornale di Geologia* 24: 268 pp.

Stuiver, M. and Polach, H. A. 1977 Discussion: Reporting of ^{14}C data. *Radiocarbon* 19(3): 355–363.

Tamers, M. A. 1960 Carbon-14 dating with the liquid scintillation counter: Total synthesis of the benzene solvent. *Science* 132: 668–669.

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REHOVOT RADIOCARBON MEASUREMENTS IV[1]

ISRAEL CARMI

Department of Environmental Sciences and Energy Research, The Weizmann Institute of Science 76100 Rehovot, Israel

and

DROR SEGAL

Israel Antiquities Authority, P. O. Box 586, 91004 Jerusalem, Israel

INTRODUCTION

The following list consists of dates of archaeological samples, obtained by gas-proportional counting of ethane, between 1985 and the end of 1991. During this time a close cooperation has been established with the Israel Antiquities Authority, which now has an archaeologist (D.S.) participating in the operation of the lab and serving as a liaison officer with the archaeological community.

To accommodate the requests of archaeologists for higher precision, the counting time was increased to at least 3.6 k min in the large counter (0.5 liter 2100 torr, 1.5 g carbon) and 5 k min in the medium counter (0.25 liter 2100 torr, 0.75 g carbon). Organic samples are now oxidized in a high-pressure combustion unit (Phonon 400). The standard used is NBS oxalic acid II.

Dates are expressed in conventional radiocarbon years, with an overall error of ±1 σ. Archaeologists are also offered, and encouraged to use, calibrated ages.

The locations of sites are given in the Natural Grid Reference (NGR) and shown on the map (Fig. 1). The numbered location on the map is given with a prefix, M, next to the NGR. We acknowledge the help of G. Carmel, who prepared the map.

MARINE SAMPLES

RT-747. Maagan Michael Ship — 2470 ± 160

Wood from a sunken ship collected 1985 by E. Linder, Center for Maritime Studies, University of Haifa, from 1. 8 m bsl (NGR 1410-2177, M16).

Comment (E.L.): Estimated 5th century BC.

RT-757. Atlit Harbor — 800 ± 120

Wood from posts of a crusader wharf from the north end of the bay of Atlit (NGR 1449-2350, M11). Collected 1985 by E. Galili, Israel Antiquities Authority.

Kinneret Boat Series

Boat found in winter 1986 in the mud near Genosar on the shore of the Sea of Galilee (NGR 1995-2500, M7). Samples 767A and 767B collected by A. Raban, Center for Maritime Studies,

[1]Contribution No. 39, Department of Environmental Sciences and Energy Research, The Weizmann Institute of Science

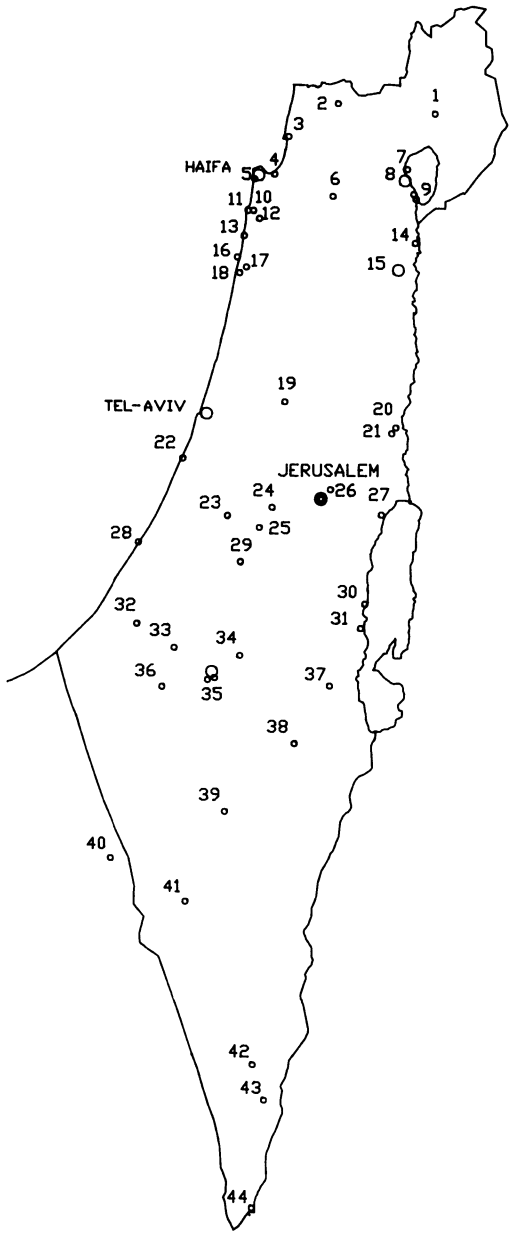

Fig. 1. Location map of archaeological sites from which the samples in this report came

1. Gesher Bnot Ya'aqov
2. Nahal Bezet/Horvat Galil
3. Acre
4. Tel Abu Hawam
5. Kefar Samir
6. Yiftah'el
7. Kinneret (boat)
8. Tiberias
9. Beth Yerah/Ohalo
10. Tel Hariz
11. Atlit Harbor
12. El Wad
13. Dor
14. Gesher
15. Beth Shaan
16. Maagan Michael
17. Beit Hananya
18. Cesarea
19. Nahal Kana
20. Gilgal
21. Netiv Hagdud
22. Palmahim
23. Tel Harasim
24. Haruv
25. Tel Yarmut
26. Nahal Zimri
27. Qumran
28. Ashqelon
29. Maresha
30. Ein Gedi
31. Nahal Mishmar
32. Nahal Metnan
33. Gilat
34. Tel Shoqet
35. Neve Noy/Beer Zfad
36. Shiqmim
37. Lahat
38. Mamshit
39. Ein Ziq
40. Kadesh Barnea
41. Nahal Oded
42. Uvda Valley
43. Ma'ale Shaharut
44. Eilat

University of Haifa. All other samples were collected by S. Wachsman, Israel Antiquities Authority. Wachsman (1990) has given a full report on all aspects of the boat.

TABLE 1. Kinneret Boat Series

RT-no.	Feature	No.	Type	^{14}C age
-767A	Strake			1940 ± 100
-767B	Frame			2080 ± 90
-772A	Strake	6		2140 ± 100
-772B	Frame	42A		1900 ± 100
-773A	Fragment of Assembly 1			1900 ± 100
-793A	Frame	78	*Quercus*	1960 ± 130
-793B	Strake	24	*Cedrus*	2000 ± 100
-793C	Strake	62	*Cedrus*	2110 ± 110
-794D	Assembly 3 beneath boat	A657/2		2030 ± 110
-794E	Strake	A61/14		2100 ± 120
-794F	Strake	46		2060 ± 120
-794G	Tenon from strake	10		1960 ± 110

Tel Hariz series

Tel Hariz is an underwater Neolithic site 7 km south of Haifa (NGR1420-2340, M10). Collected 1986 by E. Galili, from 2.5 m bsl, 30 m from the present shoreline.

RT-779A. **7330 ± 120**

Wood.

RT-779B. **6260 ± 150**

Wood. $\delta^{13}C = -25.3‰$

RT-797. Acre **2800 ± 120** $\delta^{13}C = -26.0‰$

Charcoal from a layer of ash on a stone floor between two walls in Area P. L 8034, B 8600 (NGR 1585-2585, M3). Collected 1985 by A. Raban.

RT-801. Dor Ship **1640 ± 120**

Wooden board from a sunken ship found on the beach, 25 km south of Haifa (NGR 1430-2240, M13). Collected 1986 by S. Wachsman.

RT-802. Palmahim Anchor **2080 ± 100** $\delta^{13}C = -25.8‰$

Remains of wood coating of a lead anchor found on the beach, 15 km south of Tel Aviv (NGR 1220-1480, M22). Collected 1986 by S. Wachsman.

Cesarea series

Excavations at the site of Cesarea (NGR 1402-2136, M18). Collected by A. Raban. Raban (1989) has reported on the site and excavations.

RT-809. Rope **1630 ± 130**
$\delta^{13}C = -25.4‰$

Rope from a sunken ship, in the northern bay near Straton's Tower, Area Y2, b 7004.

RT-836A. *Ostrea* **2100 ± 120**

Shells from Area S-2, L 225, at depth 1 m bsl. Collected 1986.

RT-836C. **2010 ± 100**
$\delta^{13}C = -24.8‰$

Charcoal from a ditch excavated from east to west, on dry land, Area J-3, L 327, b 8024, at depth 1.1 m under boulders. Collected 1987.

RT-836D. **1430 ± 80**

Charcoal from hole #6 under vault #1 in Area Z, b2001. Collected 1987. $\delta^{13}C = -23.6‰$

RT-836E. **1190 ± 80**

Charcoal from Area Z L 501, b 5056. Collected 1987. $\delta^{13}C = -24.0‰$

RT-878. **1050 ± 80**

Oily organic matter underlying a mosaic floor in Cesarea (L 201). Collected and submitted by A. Nissenbaum, Weizmann Institute of Science.

RT-942A. **1100 ± 200**

Rope from a sunken ship north of the port, from 2.6 m bsl. Collected 1980. $\delta^{13}C = -25.5‰$

RT-942B. **1960 ± 50**
$\delta^{13}C = -25.3‰$

Wood from a wooden envelope of a lead anchor found inside the port from 6.3 m bsl. Collected 1988 by A. Raban.

RT-1221. **1210 ± 45**

Wood from Area I-1. Collected 1989. $\delta^{13}C = -23.9‰$

Sardinia series

Excavations near Tharros, Sardinia next to the city walls. Collected 1987 by E. Linder from Area C, 2.8 m bsl. See Linder (1987) for details.

RT-849A. **1190 ± 160**

Wood. $\delta^{13}C = -25.2‰$

RT-849B. **1870 ± 110**

Wood. $\delta^{13}C = -25.2‰$

RT-849C. **1640 ± 130**

Charred wood.

RT-855. Kefar Samir **6420 ± 200**

Straw mat found near a submerged construction in Kefar Samir south of Haifa (NGR 1460-2450, M5). Collected 1987 by E. Galili. See Carmi and Segal (1990) for details.

Tel Abu Hawam series

Tel Abu Hawam is an archaeological site north of the Haifa port (NGR 1521-2450, M4). Samples are from depth 1 m, in a layer of ancient salt swamp, adjacent to the tell, containing Iron Age I remains. Collected 1988 by A. Raban (Raban & Galanti 1987).

RT-942C. **2890 ± 95**

Twigs. $\delta^{13}C = -25.2‰$

RT-942D. **2940 ± 60**

Piece of a wooden artifact. $\delta^{13}C = -23.4‰$

Atlit Yam series

Atlit Yam is a late Pre-Pottery Neolithic B (PPNB) submerged village off the shore of Atlit, 10 km south of Haifa (NGR 1449-2346, M11). Collected 1987 by E. Galili from 10 m bsl.

RT-944A. **7670 ± 85**

Charred seeds of wheat, collected 1987.

RT-944C. **7610 ± 90**

Charcoal. $\delta^{13}C = -25.7‰$

RT-1403. Atlit anchor **2320 ± 45**

Wood from an anchor, found 4 m bsl off the shore of Atlit. Collected 1988 by E. Galili.

Ein Gedi Anchor series

Ropes from stone anchors, found on the shore of the Dead Sea near Ein Gedi (NGR 1880-0970, M30). Collected 1989 by G. Hadas, Israel Antiquities Authority (Nissenbaum, Carmi & Hadas 1990).

RT-954. **2180 ± 80**

Rope from anchor C. $\delta^{13}C = -22.8‰$

RT-1202. **2200 ± 120**

Rope from anchor A.

Tiberias series

Wood from posts next to the old walls of Tiberias (NGR2016-2422, M8). Collected 1989 by A. Raban.

RT-1291. **1360 ± 50**

RT-1292. **1360 ± 50**

Continental samples

Uvda Valley series

These samples are from an archaeological excavation 40 km north of Eilat (NGR1469-9295, M42). Collected by O. Yogev (RT-724A to -724F) and U. Avner (the remaining samples), Israel Antiquities Authority (Avner 1990).

RT-724A. **1290 ± 240**
$\delta^{13}C = -10.6‰$

Uvda 7, charcoal collected 1980 from Site 7 L 907, 0.5 m below surface. Apparently, this is an Omayan intrusion into the original site.

RT-724B. **6410 ± 120**
$\delta^{13}C = -24.5‰$

Uvda 7, charcoal collected 1980 from a hearth in Site L 69, 0.2 m below surface.

RT-724C. **4540 ± 100**

Uvda 7, charcoal collected 1980 from L 110, 0.5 m below surface. $\delta^{13}C = -13.5‰$

RT-724D. **5400 ± 110**

Uvda 4, charcoal collected 1980 from L 29, 0.5 m below surface. $\delta^{13}C = -23.3‰$

RT-724E. **2320 ± 80**

Uvda 5, charcoal collected 1980 from L 16. $\delta^{13}C = -22.4‰$

RT-724F. **4015 ± 80**

Uvda 21, charcoal collected 1980 from L 17.

RT-864A. **4310 ± 100**

Uvda 9, charcoal collected 1980 from L 912, 0.6 m below surface. $\delta^{13}C = -16.7‰$

RT-864B. **4440 ± 180**

Uvda 9, charcoal collected 1980 from L 924, 0.6 m below surface. $\delta^{13}C = -23.2‰$

RT-864C. **2740 ± 90**

Uvda 9, charcoal collected 1980 from L 903, 0.3 m below surface. $\delta^{13}C = -20.6‰$

RT-899A. **4530 ± 50**

Uvda 9, charcoal collected 1984 from L 964, 0.6 m below surface. $\delta^{13}C = -16.7‰$

RT-899B. **4520 ± 60**

Uvda 9, charcoal collected 1984 from L 902, 0.4 m below surface. $\delta^{13}C = -23.5‰$

Yiftah'el series

Yiftah'el is a Neolithic (PPNB) site in the lower Galilee in the Valley of Beth Netofa (NGR 1720-2400, M6). Collected 1983 by Y. Garfinkel, Institute of Archaeology, Hebrew University, Jerusalem (Garfinkel, Carmi & Vogel 1987).

RT-736A. Horsebean **8570 ± 130**

Charred horsebean seeds from a silo in L 719, 2 m below surface. $\delta^{13}C = -22.5‰$

RT-736B. Lentil **8890 ± 120**

Charred lentil seeds from L 710, 2 m below surface. $\delta^{13}C = -22.6‰$

Comment (Y.G.): Horsebean and lentil seeds are of special significance in the domestication process.

Netiv Hagdud series

These samples are from a Pre-Pottery Neolithic A (PPNA) site in the Jordan Valley, 12 km north of Jericho (NGR 1920-1540, M21). Collected 1984 by O. Bar-Yosef and A. Gopher, University of Tel Aviv. All samples are charcoal.

RT-762A. **9680 ± 140**

$\delta^{13}C = -23.2‰$

RT-762B. **9600 ± 170**

$\delta^{13}C = -23.2‰$

RT-762C. **9970 ± 150**

RT-762D. **9400 ± 180**

$\delta^{13}C = -24.9‰$

RT-762F. **9780 ± 150**

RT-777. Gilgal I **9980 ± 150**
$\delta^{13}C = -22.9‰$

Gilgal I is a PPNA site in the Jordan Valley, 17 km north of Jericho (NGR1920-1540, M20).

Collected 1985 by T. Noy, Israel Museum, Jerusalem. The sample is charred barley seeds from a silo inside a house, 11.9 m below surface.

Ma'ale Shaharut series

Ma'ale Shaharut tombs are in a rockshelter in Wadi Shaharut in the Arava Valley, east of Uvda valley (NGR1499-9238, M43). Samples are wood, probably acacia, attributed to Middle Bronze I (MBI) and Early Bronze I (EBI). Collected 1986/7 by U. Avner.

RT-771A. B5 **2430 ± 130**

Sample from Tomb IV, 0.8 m below surface. $\delta^{13}C = -22.6‰$

RT-771B. B4 **3580 ± 130**

Sample from Tomb IV, 0.8 m below surface. $\delta^{13}C = -24.0‰$

RT-899C. **3700 ± 55**

Sample from Tomb IV, 0.6 m below surface. $\delta^{13}C = -23.0‰$

RT-899D. **3100 ± 60**

Sample from Tomb III, 0.6 m below surface. $\delta^{13}C = -22.1‰$

Lahat series

Lahat cave is in the Judean Desert, 40 km southeast of Beer Sheva (NGR1710-0680, M37). In 1986, I. Gilead, Ben Gurion University, Beer Sheva, conducted salvage excavations after the site was robbed. Chalcolithic and Roman remains were found on the bedrock.

RT-782A. Twigs, Layer C **4050 ± 120**

$\delta^{13}C = -21.2‰$

RT-782B. Charcoal, Layer B **3800 ± 100**

$\delta^{13}C = -23.4‰$

RT-783. Neve Noy **1330 ± 100**
$\delta^{13}C = -11.1‰$

Charcoal from a suburb of Beer Sheva, on the south bank of wadi Beer Sheva (NGR 1300-0710, M35). Collected 1986 by I. Gilead. Sample is from the remains of a furnace 1.5 m below surface. Byzantine sherds were found in the fill.

Gesher series

Gesher is a Neolithic (PPNA) site in the Jordan Valley, 15 km south of the outflow of the Sea of Galilee (NGR 2030-2230, M14). Collected 1986 by Y. Garfinkel.

RT-814A. **10,590 ± 140**

Charcoal collected 1986 from 4 m below surface in Area A. $\delta^{13}C = -25.2‰$

RT-814B. **10,390 ± 220**

Charcoal collected 1986 from 4 m below surface in Area A. $\delta^{13}C = -25.0‰$

RT-868A. **9820 ± 140**

Charcoal collected 1986 from 4 m below surface in Area A. $\delta^{13}C = -25‰$

RT-868B. **9790 ± 140**

Charcoal collected 1986 from 4 m below surface in Area A. $\delta^{13}C = -24.3‰$

2080 ± 80
$\delta^{13}C = -29.6‰$

RT-843. Ashqelon

Wood from the bottom of a Roman well in Tel Ashqelon (NGR 1071-1171, M28). Collected 1987 by Y. Nir, Israel Geological Service. The wood, identified as sycamore, was used as a foundation for the walls of the well, which was built from dressed kurkar stones. The well is in the kurkar precipice southeast edge of the tell.

995 ± 120
$\delta^{13}C = -24.8‰$

RT-856. Maagan Michael

Charcoal from mortar used in a dam near a water mill (NGR 1420-2170, M16). Collected 1987 by Y. Peleg, Israel Antiquities Authority.

Comment (Y.P.): The dam is a Byzantine construction (Peleg 1986).

1700 ± 85
$\delta^{13}C = -23.5‰$

RT-857. Beit Hananya

Charcoal from mortar around ceramic pipes in an aqueduct near Cesarea (NGR 1430-2150, M17). Collected 1987 by Y. Peleg.

Comment (Y.P.): The structure was a Byzantine construction.

Shiqmim series

Charcoal from a Chalcolithic village near Beer Sheva (NGR1147-0675, M36). Collected 1987 and 1989 by T. E. Levy, Hebrew Union College, Jerusalem.

RT-859B. **5460 ± 140**

Eastern deep trench field Sample 14. $\delta^{13}C = -24.0‰$

RT-859C. **5080 ± 180**

L210/B0317 from Square K/11. $\delta^{13}C = -24.0‰$

RT-859D. **5370 ± 180**

L216/B0323 from a lower village. $\delta^{13}C = -24.0‰$

RT-859E. **5390 ± 180**

L211/B0329 from a lower village.

RT-1317. **5330 ± 50**

L3294/Z750, underground subroom (SR) I near a basalt bowl.

RT-1318. **5240 ± 65**

L3262/Z617, a tunnel fill leading into SRI, near surface.

RT-1319. **5450 ± 60**

L3313/Z874, cultural fill in underground room SR9, Subphase bII.

RT-1321. **5570 ± 65**

L3327/Z902, from the floor of underground room SR9, Subphase bII.

RT-1322. **5190 ± 75**

L3304/Z839, from a sterile layer in underground room SR8, Subphase aII.

RT-1326. **5420 ± 50**

L3312/Z833, from the floor of underground room SR7, Phase II.

RT-1328. **5520 ± 60**

L3281/Z695, from underground room SRII, Phase IIb.

RT-1329. **4260 ± 80**

L3290/Z728, from a hearth on the floor of SRIII. $\delta^{13}C = -22.3‰$

RT-1330. **5300 ± 60**

L3293/Z744, from a pit in underground room SR6/7, Subphase c, dII.

RT-1332. **4700 ± 80**

L3292/Z747, aeolian fill in underground room SR6, Subphase bII.

RT-1334. **5590 ± 60**

L3335/Z913, from fill in underground room SR10, Subphase CIII. $\delta^{13}C = -23.9‰$

RT-1335. **5370 ± 65**

L434/B7308, from between the walls of possible Altar 2.

RT-1339. **4940 ± 70**

L3055/Z201, from a Phase bII burial pit.

RT-1341. **5370 ± 40**

L3256/Z569, from Phase I(2) court. $\delta^{13}C = -24‰$

Gilat series

Charcoal from a Chalcolithic village 13 km northwest of Beer Sheva (NGR 1170-0830, M33). Collected 1987 by T. E. Levy, Hebrew Union College, Jerusalem.

RT-860A. **5440 ± 180**

L128/B5180, from the base of a stone-lined silo in Stratum III. $\delta^{13}C = -24.3‰$

RT-860B. **4800 ± 135**
$\delta^{13}C = -24.3‰$

L92/B595, from a rubbish pit in Stratum II, with penetrated stand and a predynastic-style granite head.

Nahal Kana series

Charcoal samples from an active karstic burial cave at elevation 210 m asl in Samariya, 25 km northeast of Tel Aviv (NGR1550-1680, M19). The first two samples (A, B) and the last two samples (D, E) are Chalcolithic, and were associated with gold artifacts. The remaining sample (C) is from another room in the cave, with Pottery Neolithic (PN) remains. Collected by A. Gopher, University of Tel Aviv.

RT-861A. **5150 ± 190**

L 104 B 1172B 1100, collected 1986.

RT-861B. **6010 ± 150**

L 142 B 1549, collected 1987.

RT-861C. **5240 ± 180**

L 143, L 130 B 1534, B 1555, collected 1987. $\delta^{13}C = -25.4‰$

RT-861D. **6980 ± 190**

L 409, collected 1987. $\delta^{13}C = -26‰$

RT-861E. **5440 ± 100**

L 125, B 1245, collected 1987. $\delta^{13}C = -23.4‰$

RT-862C. Beer Zfad (Bir Safadi) **5220 ± 105**

Charcoal from L 160 in a system, L-144, of a subterranean room of Phase 3 on the bank of Wadi Beer-Sheva, Beer Sheva (NGR 1280-0700, M35). Collected 1982 during a salvage excavation by I. Eldar, Israel Antiquities Authority. The site was excavated previously by J. Perrot in the 1950s (Eldar & Baumgarten 1985).

Tel Shoqet series

Charred organic matter from a bell-shaped hole under the floor of a Chalcolithic house near Tel Shoqet junction, 15 km northeast of Beer Sheva (NGR 1407-0795, M34). Collected 1987 by Y. Guvrin, The Negev Museum, Beer Sheva.

RT-863A. **4620 ± 170**

L 17 B 86. $\delta^{13}C = -21.8‰$

RT-863B. **5490 ± 140**

L 17 B 96. $\delta^{13}C = -21.0‰$

RT-879. Ein Gedi **210 ± 120**

Wood branch (jujube) found in a wall of a water mill near Ein Gedi spring (NGR 1986-0971, M30). Collected 1987 by G. Hadas.

Nahal Metnan series

Nahal Metnan is an Early Arabic site in the Western Negev Highlands (NGR1034-0095, M32). Collected by M. Haiman, Israel Antiquities Authority; submitted 1987 (Haiman 1990).

RT-884. **1455 ± 95**

L103 B1022.

RT-934. **1515 ± 55**

$\delta^{13}C = -23.6‰$

Ein Ziq series

Charcoal from Ein Ziq, near Sede Boqer, 50 km south of Beer Sheva (NGR 1355-0225, M39). Collected 1987 by O. Bar-Yosef.

RT-885A. **3960 ± 90**

L 53 B282. $\delta^{13}C = -22.5‰$

RT-885B. **4760 ± 80**

L 79 B422.

RT-897. Nahal Oded **1290 ± 40**
$\delta^{13}C = -21.8‰$

Charcoal from a Byzantine/Early Arabic site in the southern Negev (NGR 1217-9907, M41). Collected by S. Rosen, Ben Gurion University, Beer Sheva; submitted 1988 (Rosen & Avni 1989).

Kadesh Barnea series

Charred cereal seeds from an Iron-Age fortress in Kadesh Barnea, north Sinai (NGR0960-0050, M40). Collected 1978 by R. Cohen, Israel Antiquities Authority.

RT-898. **2600 ± 45**

Sample from Square D6, L523, B994. $\delta^{13}C = -21.2‰$

RT-933. **3080 ± 45**

Sample from the upper fortress. $\delta^{13}C = -21.9‰$

Qumran series

Samples from Cave 24 in the Qumran site, Dead Sea shore (NGR1935, 1294, M27). Collected 1988 by Y. Garfinkel.

RT-907A. **9720 ± 100**

Charcoal from a fire. $\delta^{13}C = -11.6‰$

RT-907B. **9010 ± 150**

Piece of wood. $\delta^{13}C = -25.3‰$

RT-907C. **8540 ± 90**

Charcoal from a fire. $\delta^{13}C = -15.3‰$

RT-907D. **6450 ± 65**

Charcoal from a fire.

RT-907E. **1800 ± 95**

Goat dung. $\delta^{13}C = -21.4‰$

Comment (Y.G.): Archaeological finds in the cave range from Neolithic to Roman periods.

RT-924B. Hartuv **4645 ± 55**
$\delta^{13}C = -24.2‰$

Charcoal from L 162 from this EBI site, 20 km southwest of Jerusalem (NGR 1500-1300, M24). Submitted 1988 by O. Bar-Yosef.

RT-925A. Tel Yarmut **4920 ± 90**
$\delta^{13}C = -24.2‰$

Charcoal from a sealed construction from this EBIII site, 20 km west of Jerusalem (NGR 1240-1470, M25). Submitted 1989 by O. Bar-Yosef.

Eilat IV series

Samples are from Tomb IV in a field of tumuli in Eilat (NGR 1435-8855, M44). Collected July 1988 by U. Avner.

RT-926A. **6340 ± 60**

Charcoal from Hearth 4 next to the tomb, from 20 cm below surface. $\delta^{13}C = -23.6‰$

RT-926B. **5400 ± 100**

Charcoal from Hearth 1 next to the tomb. $\delta^{13}C = -23.6‰$

RT-989. **6470 ± 60**

Charcoal from the base of the tomb, at 80 cm depth, B16.

RT-1210. **5710 ± 75**

Pieces of wood from 20 cm below surface next to the tomb. $\delta^{13}C = -20.2‰$

Eilat V series

Samples are from Tomb V in a field of tumuli in Eilat (NGR 1435-8855, M44). Collected July 1988 by U. Avner.

RT-1211. **5640 ± 60**

Charcoal from Hearth 16, 20 cm below surface. $\delta^{13}C = -24.4‰$

RT-1212. **5930 ± 80**

Charcoal from Hearth 18, 20 cm below surface. $\delta^{13}C = -23.8‰$

RT-1213. **5490 ± 60**

Charcoal from Hearth 19, 20 cm below surface. $\delta^{13}C = -22.7‰$

RT-1214. **5980 ± 130**

Charcoal from Hearth 22, 20 cm below surface.

RT-1215. **6400 ± 210**

Charcoal from Hearth 27, 15 cm below surface.

RT-1216. **6060 ± 65**

Charcoal from Hearth 28, 15 cm below surface.

Beth Yerah series

Beth Yerah is an EB site on the western beach of the Sea of Galilee (NGR2040-2350, M9). Collected 1985 by O. Yogev, to define the transition from EBI to EBII at the site.

RT-927A. **4540 ± 90**

Charcoal from stone Hearth L185 B794. $\delta^{13}C = -22.9‰$

RT-927B. **4650 ± 80**

Charcoal from brick tabun L604 B1378. $\delta^{13}C = -24.1‰$

RT-927D. **4650 ± 115**

Charcoal from the floor of room L 615 B1404. $\delta^{13}C = -23.9‰$

RT-927E. **4510 ± 90**

Charcoal from brick construction L644 B1538. $\delta^{13}C = -23.2‰$

Gesher Bnot Ya'aqov series

This is a prehistoric site on the Jordan River (NGR 2090 2680, M1). Collected by N. Goren-Inbar, Institute of Archaeology, Hebrew University, Jerusalem (Goren-Inbar 1991).

RT-932. **38,500 ± 17**
$\delta^{13}C = -27.7‰$

A piece of partly exposed wood (*Fraxinus syriaca*) from 10 cm below surface.

RT-961. **34,700 ± 90**
$\delta^{13}C = -25.2‰$

A piece of wood (*Pistacia atlantica*) from a layer of Bnot Ya'aqov formation.

Ohalo II series

Charred wood and seeds from a prehistoric excavation on the southwestern shore of the Sea of Galilee (NGR2039-2362, M9). Collected 1989 by D. Nadel, Prehistoric Museum, Haifa.

RT-1244. **18,360 ± 230**

Sample C89a. $\delta^{13}C = -21.5‰$

RT-1246. **15,550 ± 13**

Sample AB87. $\delta^{13}C = -20.9‰$

RT-1248. **19,800 ± 360**

Sample B89c.

RT-1250. **19,250 ± 400**

Sample B89b. $\delta^{13}C = -24.4‰$

RT-1251. **19,000 ± 190**

Sample B85b. $\delta^{13}C = -22.2‰$

RT-1252. **18,900 ± 400**

Sample B89b.

RT-1297. **17,500 ± 200**

Sample E866. $\delta^{13}C = -22.7‰$

RT-1342. **18,600 ± 220**

Sample B86d. $\delta^{13}C = -19.5‰$

RT-1343. **19,500 ± 170**

C85c.

Comment (D.N.): Ohalo is an early Kebaran site.

Beth Shaan series

Excavations of the theater at Beth Shaan East (NGR 1973-2122, M15). Collected 1990 by D. Segal.

RT-1310. **1440 ± 60**

Charcoal collected next to furnace Area L 3271. $\delta^{13}C = -24.5‰$

RT-1311. **1470 ± 75**

Charcoal collected from Furnace L 50618 B. $\delta^{13}C = -24.6‰$

RT-1406. **310 ± 50**
$\delta^{13}C = -21.9‰$

Charcoal collected between Wall 1 and the underlying stylobate in Area G, B 64643.

El-Wad series

Charcoal from a prehistoric early Natufian cave in Mount Carmel, 20 km south of Haifa (NGR 1480-2310, M12). Collected 1989 by M. Evron, University of Haifa.

RT-1367. **10,680 ± 190**

Sampled from Square G38/b, Room III, depth 17 cm. $\delta^{13}C = -11.0‰$

RT-1368. **12,950 ± 200**

Sampled from Square E41/C+d, Room III, depth 46 cm. $\delta^{13}C = -25.3‰$

Maresha series

Samples are from a Hellenistic site in Maresha (NGR1400-1110, M29), excavated by A. Kloner. Collected 1990 by D. Segal.

RT-1384. **2370 ± 45**

Charcoal from the southern wall in the western section, Area 100. $\delta^{13}C = -22.5‰$

RT-1385. **2280 ± 80**

Charcoal from the fill in an excavated rectangular basin, Area 30 L34. $\delta^{13}C = -22.7‰$

RT-1386. **2270 ± 90**
$\delta^{13}C = -22.7‰$

Charcoal from a shallow layer, 2 cm thick, in the central hall of System 75, L2035.

RT-1387. **2100 ± 40**

Organic matter from an olive-oil press collecting system, from Area 44. $\delta^{13}C = -23.4‰$

Upper Galilee Prehistory series

Samples are from two PPNB sites in the Upper Galilee (NGR 1732-2731, M2), collected by A. Gopher.

RT-1394. Nahal Bezet I **8330 ± 100**
$\delta^{13}C = -25.6‰$

Charcoal from the floor of circular construction #1, Square K-9, collected 1987.

RT-1395. Nahal Bezet I **7400 ± 65**

Charcoal from a hearth in Square K-7, collected 1987. $\delta^{13}C = -25.0‰$

RT-1397. Horvat Galil **9340 ± 70**

Charcoal from Square G-11d, collected 1989. $\delta^{13}C = -25.6‰$

RT-1396. Horvat Galil **8950 ± 100**

Charcoal from a posthole in construction #1, collected 1989.

RT-1400. Tel Harasim **2740 ± 70**
$\delta^{13}C = -25.2‰$

Charcoal from Layer V, Area A-3 (NGR 1340-1280, M23). Collected 1990 by D. Inbar.

Nahal Mishmar series

Samples from the Chalcolithic treasure cave in Nahal Mishmar in the Judean Desert, west of the Dead Sea (NGR 1810-0880, M31). Collected 1961 P. Bar Adon and stored for 30 years before dating (Bar Adon 1980).

RT-1407. Mat **4990 ± 70**
$\delta^{13}C = -9.2‰$

The style of this mat is similar to that in which the treasure was packed, from Cave I, Alcove A B-11/2.

RT-1409. **5355 ± 55**

Piece of wood, possibly from a loom. $\delta^{13}C = -26.0‰$

RT-1410. **2385 ± 55**

Charcoal found in the cave.

RT-1415. Mamshit **1670 ± 45**
$\delta^{13}C = -22.8‰$

Piece of cypress from storage of wood planks excavated in Mamshit, in the Negev (NGR 1560-0480, M38). Submitted by N. Lifshitz, University of Tel Aviv.

RT-1416. Nahal Zimri **3490 ± 90**
$\delta^{13}C = -22.8‰$

Charcoal from a site in northern Jerusalem, near wadi Zimri, 683 m asl (NGR 1734-1365, M26). Collected by I. Meitlis, Israel Antiquities Authority, from a room in a public building in a MBII village, Layer 2 L364 B3492.

References

Avner, U. 1990 Ancient agricultural settlement and religion in the Uvda Valley in southern Israel. *Biblical Archaeologist* 53: 125–141.

Bar Adon, P. 1980 The Cave of the Treasure, Jerusalem. *Israel Exploration Society* 180–195.

Carmi, I. and Segal, D. 1990 14C dates of samples from an underwater site in Kefar Samir, Mitekufat Haevan. *Journal of the Israel Prehistory Society* 23: 152.

Eldar, I. and Baumgarten, Y. 1985 Neve Noy Chalcolitic site of the Beer-Sheva culture. *Biblical Archaeology* 48: 134–139.

Garfinkel, Y. and Nadel, D. 1989 The Sultanian flint assemblage from Gesher and its implications for recognizing Early Neolithic entities in the Levant. *Paléorient* 15/2: 139–151.

Garfinkel, Y., Carmi, I. and Vogel, J. C. 1987 Dating of horsebean and Lentil seeds from the Pre-Pottery Neolithic B village of Yiftah'el. *Israel Exploration Journal* 37: 40–42.

Goren-Inbar, N. 1991 The Acheulian site of Gesher Benot Ya'akov – an Asian or an African Entity? *In* Akazawa, T., ed., *The Evolution and Dispersal of Modern Humans in Asia.* The University of Tokyo Symposium, 14–17 November 1990.

Haiman, M. 1990 An agricultural settlement in Ramat Barnea in the seventh-eight centuries CE. *Atiqot* 10: 111–124 (in Hebrew with an English summary).

Linder, E. 1987 The maritime installation of Tharros (Sardinia). A recent discovery. *Rivista di Studi Fenici* XV: 47–55.

Nissenbaum, A., Carmi, I. and Hadas, G. 1990 Dating of ancient anchors from the Dead Sea. *Naturwissenschaften* 77: 228–229.

Peleg, J. 1986 Das Stauwerk fuer untere Wasserleitung nach Caesarea. *Mitteilungen des Leichtweiss Institut* 89.

Raban, A. 1989 The harbours of Caesarea Maritime. Results of the Caesarea Maritime: Results of the Casesarea Ancient Harbour Excavation Project, 1980–1985, Vol. 1: The site and the excavations. *BAR International Series* 491: 518

Raban, A. and Galanti, I. 1987 Tel Abu Hawam, 1985. *Israel Exploration Journal* 37: 179–181.

Rosen, S. A. and Avni, G. 1989 Har Oded, 1988. *Israel Exploration Journal* 39: 117–120.

Wachsman, S. 1990 The excavation of an ancient boat (Lake Kinneret). *Atiqot* 19: 1–138.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 133–139]

UNIVERSITY OF GRANADA RADIOCARBON DATES VI

CECILIO GONZALEZ-GOMEZ

Laboratorio de Datación por Carbono-14 and Instituto Andaluz de Geología Mediterránea (IAGM) del CSIC, Facultad de Ciencias, Universidad de Granada, E-18071 Granada, Spain

INTRODUCTION

This paper includes determinations of archaeological, geological, palaeobotanical and other samples from Spain, Portugal and Bolivia, measured at the University of Granada Radiocarbon Dating Laboratory, mostly from 1989 to 1990. Pretreatment of charcoal and wood samples is a standard acid-basic procedure using 8% HCl and 2% NaOH at boiling temperature. We obtain collagen from bone samples using the Longin (1971) method.

The method of dating is benzene synthesis and liquid scintillation counting as previously reported (González-Gómez, López-González and Domingo-García 1982; González-Gómez, Sánchez-Sánchez and Domingo-García 1985; González-Gómez, Sánchez-Sánchez and Villafranca-Sánchez 1986, 1987; González-Gómez and Sánchez-Sánchez 1991), but in this case, we changed the sample size and the scintillator, using 7 ml low ^{40}K Packard counting picovials with 5 ml synthesized benzene and 83.5 mg Butyl-PBD directly dissolved in the benzene (16.7 g/l) as a scintillator; smaller samples were made up to 5 ml with inactive benzene. ^{14}C activity was measured in a Packard Tri-Carb Mod 4640 liquid scintillation spectrometer. Efficiency was ~68%, using the part of the spectrum above the end point of tritium, with a background of ~7.2 cpm. At least one modern reference standard and two background vials were measured together with each series of measurements. All results are corrected for fractionation according to the quoted $\delta^{13}C$ (w.r.t. PDB) values.

In order to prevent any loss of benzene during counting and storage, we sealed the vials hermetically with a metallic cap. The joint is made of 3 mm silicon + 0.05 mm teflon sheet. For a second barrier, we placed a silicon O-ring, 10 mm in inner diameter and 2 mm thick, around the neck of the vial. The weight of the vials, checked one year after filling, remains constant.

Dates reported here are based on 0.95 of the activity of NBS oxalic acid modern standard, on the Libby ^{14}C half-life of 5568 years, and expressed in radiocarbon years relative to AD 1950, as suggested by Stuiver and Polach (1977). Samples were measured for 100 min repeated 40–45 times, as well as background and standard vials. The standard deviation quoted includes only 1 σ of the counting statistics of background, sample and modern standard counts. Calculations and data are processed by a PC computer, using a general program for radiocarbon dating laboratories made by González-Gómez (Computer general program for radiocarbon dating laboratories, ms in preparation). Calibrated ages for a 2 σ interval are obtained by the method of Pearson *et al.* (1986) running the computer programs CALIB (Stuiver & Reimer 1986) and CALI (González-Gómez, CALI, a computer program for calibration of radiocarbon dates, ms. in preparation) using the bidecadal curve for samples of atmospheric origin.

Sample descriptions and comments are based on information supplied by submitters of samples.

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ARCHAEOLOGICAL SAMPLES

SPAIN

UGRA-326. AMAREJO — **2050 ± 70** — $\delta^{13}C = -25.9‰$

Charcoal from El Amarejo (38°31′N, 2°20′W), Bonete, Albacete province. The sample, from 3 m depth, was collected and submitted 1985 by S. Broncano-Rodríguez, Ministry of Cultura, Madrid, to date the time of deposit of some Iberian ceramics, needles, beads, *etc.*, at the site.

Comment: Expected age: ~3200 ± 60 BP; 349 cal BC–cal AD 80.

El Castillo de Burgos series

Samples from El Castillo de Burgos (Burgos Castle) (42°20′N, 3°43′W) were collected 1985 by J. M. Martínez-González and submitted 1985 by J. L. de Uribarri-Angulo to date cultural stages at the end of the Bronze Age and the beginning of the Iron Age. Other samples from El Castillo de Burgos were dated previously (González-Gómez & Sánchez-Sánchez 1991: 369).

UGRA-333. SII-NV-M3 — **2590 ± 90**

Charcoal from 1.68 m depth; 920–410 cal BC. — $\delta^{13}C = -25.6‰$

UGRA-334. SII-NVI-M4 — **2400 ± 110**

Charcoal from 1.75 m depth; 810–200 cal BC. — $\delta^{13}C = -24.9‰$

UGRA-339. No.7 Nivel X — **3230 ± 70**

Charcoal from 1.96 m depth; 1680–1400 cal BC. — $\delta^{13}C = -24.8‰$

General Comment: Expected age: ~2720 ± 250 BP.

Castillo de Monturque series

Samples from Castillo de Monturque (37°29′N, 4°35′W), Monturque, Córdoba province, were collected and submitted 1987 by L. A. López-Palomo, Delegación Provincial de Cultura, Córdoba, to date the Chalcolithic period in the Córdoba countryside, a very strong campanulate stage. The samples were dated to find a correlation between agricultural activities and traditional stages of the pre- and proto-history of the Guadalquivir Valley.

UGRA-303. MONT (87)-3 — **4120 ± 160**

Charcoal from 5.90 m depth; 2910–2470 cal BC. Expected age: ~3910 ± 150 BP.

UGRA-308. MONT (87)-2 — **3040 ± 90**

Charcoal from 4 m depth; 1420–1165 cal BC. Expected age: ~3360 ± 100 BP.

UGRA-311. MONT (87)-1 **3190 ± 120**
$\delta^{13}C = -23.4‰$

Charcoal from 2.25 m depth; 1740–1165 cal BC. Age is older than expected: 2610 ± 50 BP.

UGRA-323. MONT (87)-4 **3390 ± 110**
$\delta^{13}C = -25.1‰$

Charcoal from 6.75 m depth; 2011–1440 cal BC. Age is younger than expected: ~4310 ± 150 BP.

UGRA-336. N=IA/C-1 Z=188 **4510 ± 110**
$\delta^{13}C = -23.8‰$

Charcoal from Cova Puntassa (40°43′N, 0°05′E), Corachar, Castellón de la Plana province. The sample, from 0.46 m depth, was collected 1985 by J. A. Casabó-Bernard and submitted 1985 by V. Palomar-Macián, Research Service Archaeology & Prehistory County Council, Castellón de la Plana, to date the transition from Eneolithic to Bronze Age in this region.

Comment: 3597–2910 cal BC. Age is older than expected: ~3860 ± 100 BP.

Cova del Tossal de la Font series

Samples from Cova del Tossal de la Font (40°07′N, 0°08′W), Villafamés, Castellón de la Plana province, were collected and submitted 1985 by F. Gusi-Jener, Research Service Archaeology & Prehistory County Council, Castellón de la Plana, to date the transition from Eneolithic to the initial Bronze Age in the middle of the Castellón de la Plana province.

UGRA-335. C-1 Z=215-300 **4140 ± 100**

Charcoal from 1.13–1.98 m depth; 2920–2470 cal BC. $\delta^{13}C = -24.7‰$

UGRA-338. C-2 Z=233 **4760 ± 70**

Charcoal from 1.21 m depth; 3700–3360 cal BC. $\delta^{13}C = -24.0‰$

General Comment: Expected ages: ~3860 ± 100 BP.

UGRA-327. C PUERTO **5170 ± 110**
$\delta^{13}C = -18.3‰$

Bones from Cortijo del Puerto (37°32′N, 3°55′W), Castillo de Locubín, Jaén province, were collected and submitted 1986 by R. Alvarez de Morales.

Comment: Sample from 3 m depth; no expected age; 4295–3707 cal BC.

Cueva del Murciélago series

Charcoal from Cueva del Murciélago (39°49′N, 0°13′W), Altura, Castellón de la Plana province. The samples were collected and submitted 1985 by V. Palomar-Macián.

UGRA-341. CI/NIII **1620 ± 70**
$\delta^{13}C = -24.8‰$

Comment: Sample from 1 m depth; cal AD 250–600. Age is younger than expected: ~2660 ± 100 BP. Dates the end of the Bronze Age and its relation to the urnfields in the Iberian culture.

3030 ± 110
UGRA-342. CI.NIV-R1Z135-R2Z136
$\delta^{13}C = -24.2‰$

Comment: Sample from 1.25–1.36 m depth; 1520–942 cal BC. Expected age: 2810 ± 50 BP. Dates the transition from the Bronze Age to the Iron Age.

3520 ± 90
UGRA-344. CI-NV-Z156-Z180
$\delta^{13}C = -24.2‰$

Comment: Sample from 1.56–1.80 m depth; 2133–1640 cal BC. Expected age: ~2910 ± 50 BP. Dates the last Bronze Age period and its relation to the Iron Age.

Morra del Quintanar series

Charcoal from Morra del Quintanar (39°01′N, 2°27′W), Munera, Albacete province. The samples were collected and submitted 1987 by C. Martín-Morales, Instituto de Conservación y Restauración de Bienes Culturales, Ministry of Cultura, Madrid, to date the use of a wall in a fortress and its relation to the central area of the site; the samples are from a fire on the outside of this wall. Other samples of Morra del Quintanar were previously dated by González-Gómez, López-González and Domingo-García (1982:219), González-Gómez, Sánchez-Sánchez and Domingo-García (1985:612) and González-Gómez, Sánchez-Sánchez and Villafranca-Sánchez (1986: 1203).

UGRA-310. Q-10A-86-48 **3920 ± 80**

Sample from 1.2 m depth; 2851–2147 cal BC. $\delta^{13}C = -24.6‰$

UGRA-312. Q-10T-85-5 **3830 ± 100**

Sample from 1 m depth; 2577–1985 cal BC. Expected age: ~3450 BP. $\delta^{13}C = -23.3‰$

UGRA-315. Q-10-85-39 **3770 ± 90**

Sample from 2.5 m depth; 2470–1950 cal BC. Expected age: ~3650 BP. $\delta^{13}C = -23.4‰$

5510 ± 300
UGRA-329. PPU 18
$\delta^{13}C = -23.4‰$

Bones from Papauvas (37°16′N, 7°03′W), Aljaraque, Huelva province, were collected 1981 and submitted 1983 by J. C. Martín de la Cruz, Department of Prehistory and Archaeology, Universidad Autónoma, Madrid, to determine if bones were from the Chalcolithic period. Another sample from Papauvas was previously dated by González-Gómez, Sánchez-Sánchez and Villafranca-Sánchez (1986: 1202). This sample dates a deeper level in the site.

Comment: Sample from 2.2 m depth; 5060–3700 cal BC.

3420 ± 80
UGRA-345. R. OLVERA 2B
$\delta^{13}C = -23.2‰$

Charcoal from Rincón de Olvera (38°01′N, 3°19′W), Ubeda, Jaén province. The samples were collected 1980 and submitted 1986 by J. Carrasco-Rús, Department of Prehistory, University of Granada, to date the Argaric culture in Jaén province. Other samples from Rincón de Olvera were previously dated by González-Gómez, Sánchez-Sánchez and Domingo-García (1985: 611). This analysis is a repetition of UGRA-73 and the result agrees with others at the site.

Comment: 1940–1520 cal BC.

PORTUGAL

Alegrios series

Charcoal from Alegrios (40°04'N, 7°08'W), Monsanto, Idanha-a-Nova, Beira Baixa province. The samples were collected and submitted 1987 by R. M. da Rosa Vilaça, Faculdade de Letras, Universidade de Coimbra, to date the settlement, in the inner Beira, of a Late Bronze Age village with Atlantic bronze metallic materials.

UGRA-305. ALG-87 I G-6 03 **3650 ± 80**

Sample from 0.68 m depth; 2280–1781 cal BC.

UGRA-306. ALG-87 I G-7 03 **2480 ± 90**

Sample from 0.85 m depth; 820–390 cal BC.

General Comment: Expected ages: ~2750 ± 100 BP.

GEOLOGICAL SAMPLES

SPAIN

Braña de Ano series

Peat from Braña de Ano (43°06'N, 4°01'W), Bárcena de Pie de Concha, Cantabria province, was collected and submitted 1989 by L. Salas-Gómez, DCITTYM, Division de Ciencias de la Tierra, Universidad de Cantabria, to study the climate in Cantabria during the Holocene.

UGRA-325. A 1 **1090 ± 80**

Sample from 0.1 m depth; cal AD 770–1113. $\delta^{13}C = -28.1‰$

UGRA-343. A 2 **4130 ± 140**

Sample from 2 m depth; 3040–2330 cal BC. $\delta^{13}C = -27.9‰$

UGRA-316. STP-CAZ **Modern**
$\delta^{13}C = -27.6‰$

Wood from Santopetar (37°26'N, 2°02'W), Taberno, Almería province, was collected 1988 by A. Martín-Penela and submitted 1988 by L. García-Rossell, Instituto Andalúz de Geología Mediterránea, CSIC, Universidad de Granada, to study the desertification process in the Almanzora River basin.

Comment: Sample from 1 m depth, is not representative of the process in the study because the desertification process in this area is older.

Sierrapando series

Peat from Sierrapando (43°21'N, 4°02'W), Torrelavega, Cantabria province, was collected and submitted 1989 by L. Salas-Gómez, DCITTYM, Division de Ciencias de la Tierra, Universidad de Cantabria, to study the climate in Cantabria during the Holocene.

UGRA-331. S 1 **680 ± 90**

Sample from 0.1 m depth; cal AD 1180–1420. $\delta^{13}C = -25.8‰$

UGRA-340. S 2 **2290 ± 60**

Sample from 1.3 m depth; 410–200 cal BC. $\delta^{13}C = -29.2‰$

9590 ± 120
$\delta^{13}C = -28.7‰$

UGRA-317. Pena Vella

Peat from Turbera de Pena Vella (43°27′N, 7°31′W), Labrada, Abadín, Lugo province. The sample, from 2.5 m depth, was collected 1988 by M. J. Aira-Rodríguez and submitted 1988 by F. Díaz-Fierros Viqueira, Department of Edafology, Fac. Pharmacy, Universidad de Santiago de Compostela, La Coruña province. The date will be compared with the pollen analysis.

PALAEOBOTANICAL SAMPLES

SPAIN

2630 ± 80
$\delta^{13}C = -26.1‰$

UGRA-318. PA 88/151

Charcoal from Castro de Penalba (42°33′N, 8°33′W), Campo Lameiro, Pontevedra province. The sample was collected 1989 by P. Ramil-Rego and A. Alvarez-Núñez and submitted 1989 by M. J. Aira-Rodríguez, Department of Botany, Faculty Pharmacy, Universidad de Santiago de Compostela, La Coruña province, to study the transition from the Late Bronze Age to the end of the Iron Age.

Comment: 930–540 cal BC; expected age: ~2600 BP.

5880 ± 90
$\delta^{13}C = -28.5‰$

UGRA-319. LL. C. 1

Peat from Llano de la Cruz (43°21′N, 7°30′W), Abadín, Lugo province. The sample was collected 1989 by P. Ramil-Rego and submitted 1989 by M. J. Aira-Rodríguez for a palaeobotanical study of the Sierra del Xutral.

Comment: 4995–4530 cal BC.

5490 ± 90
$\delta^{13}C = -29.2‰$

UGRA-330. VEIRA 1

Peat from Pena Veira (43°21′N, 7°30′W), Abadín, Lugo province, as UGRA-319.

Comment: 4510–4049 cal BC.

Puerto de la Morcuera series

Peat from Puerto de la Morcuera (40°50′N, 3°50′W), Miraflores de la Sierra, Madrid province.

Samples were collected and submitted 1989 by M. J. Gil-García, Department of Geology, Universidad de Alcalá de Henares, Madrid province, to confirm the pollen data of vegetation and climate for this area.

UGRA-321. PM-III **1440 ± 110**

Sample from 1.4–1.5 m depth; cal AD 400–790. $\delta^{13}C = -27.0‰$

UGRA-322. PM-VIII **1710 ± 90**

Sample from 1.3–1.4 m depth; 110–540 cal BC. $\delta^{13}C = -29.2‰$

UGRA-362. PM-VII **640 ± 50**

Sample from 0.5–0.6 m depth; cal AD 1270–1410. $\delta^{13}C = -27.7‰$

1830 ± 110

UGRA-324. STAM I $\delta^{13}C = -28.1‰$

Peat from Santa María I (40°56′N, 3°53′W), Oteruelo del Valle, Madrid province. The sample was collected 1988 by R. Vázquez-Gómez and submitted 1989 by M. Peinado-Lorca, Department Vegetal Biology, Faculty of Sciences, Universidad de Alcalá de Henares, Madrid province, to confirm the pollen data in order to establish the vegetation history of this area.

Comment: 90 cal BC–cal AD 430.

Special Sample

Bolivia

280 ± 60

UGRA-332. $\delta^{13}C = -28.1‰$

Wood from a violin peg. The violin has an inscription, 'Amathius Cremona 1676'. The sample is from Bolivia, submitted 1990 by F. Aragón, to confirm the age of the violin, that appears to be made by Amathius in Cremona (Italy) in the year stated above.

References

González-Gómez, C., López-González, J. D. and Domingo-García, M. 1982 University of Granada radiocarbon dates I. *Radiocarbon* 24(2): 217–221.

González-Gómez, C., Sánchez-Sánchez, P. and Domingo-García, M. 1985 University of Granada radiocarbon dates II. *Radiocarbon* 27(3): 610–615.

González-Gómez, C., Sánchez-Sánchez, P. and Villafranca-Sánchez, E. 1986 University of Granada radiocarbon dates III. *Radiocarbon* 28(3): 1200–1205.

_____1987 University of Granada radiocarbon dates IV. *Radiocarbon* 29(3): 381–388.

González-Gómez, C., and Sánchez-Sánchez, P. 1991 University of Granada radiocarbon dates V. *Radiocarbon* 33(3): 367–373.

Longin, R. 1971 New method of collagen extraction for radiocarbon dating. *Nature* 230: 241–242.

Pearson, G. W., Pilcher, J. R., Baillie, M. G. L., Corbet, D. M. and Qua, F. 1986 High-precision ^{14}C measurements of Irish oaks to show the natural ^{14}C variations from AD 1840 to 5210 BC. *In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2B): 911–934.

Stuiver, M. and Polach, H. 1977 Discussion: Reporting of ^{14}C data. *Radiocarbon* 19(3): 355–363.

Stuiver, M. and Reimer, P. J. 1986 A computer program for radiocarbon age calibration. *In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2B): 1022–1030.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 141–154]

UNIVERSITY OF WISCONSIN RADIOCARBON DATES XXVII

CHRISTINE A. PRIOR[1] and LORI F. PHELPS

Center for Climatic Research, Institute for Environmental Studies, University of Wisconsin–Madison, 1225 West Dayton Street, Madison, Wisconsin 53706 USA

INTRODUCTION

Procedures and equipment used in the University of Wisconsin laboratory have been described previously (Bender, Bryson & Baerreis 1965; Steventon & Kutzbach 1986). Except as otherwise indicated, wood, charcoal and peat samples are pretreated with dilute $NaOH\text{-}Na_4P_2O_7$ and dilute HCl before conversion to counting gas methane; when noted, marls and lake cores are treated with acid only.

The dates reported are based on the 5568-year half-life of ^{14}C. The standard deviation quoted includes only 1 σ of the counting statistics of background, sample and standard counts. Background methane is prepared from anthracite (standard methane from NBS oxalic acid). The activities of the dated samples for which $\delta^{13}C$ values are listed and the standard methane have been corrected to correspond to a $\delta^{13}C$ value of −25‰.

Sample descriptions are based on information supplied by those who submitted samples.

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ARCHAEOLOGICAL SAMPLES

UNITED STATES

Illinois

Marlen Miller (11HA318) series

Wood charcoal and nutshell collected 1988 from the Marlen Miller Site, Hancock County (40°25′N, 91°00′W) by R. Wagner and submitted by L. Conrad, Western Illinois University Archaeological Research Laboratory. The samples provide radiometric dates for a ceramic assemblage dominated by Weaver Plain.

1510 ± 60

WIS-2115. $\delta^{13}C = -25.9‰$

Sample from Feature 12, a Weaver Phase, flat-bottomed pit containing nut-processing tools, Weaver rim sherds and preserved floral remains.

[1]Present address: Department of Anthropology, Institute of Geophysics and Planetary Physics, University of California, Riverside, California 92512 USA

WIS-2116. **1620 ± 60**
$\delta^{13}C = -26.4‰$

Sample from Feature 20, a vertical walled, flat-bottomed pit containing reconstructible Weaver Plain vessels, floral and faunal remains.

WIS-2117. **1440 ± 50**
$\delta^{13}C = -25.9‰$

Sample from Feature 25, a Weaver Phase basin-shaped pit feature superimposed by another Weaver Phase pit containing reconstructible sections of a noded, Weaver Plain vessel and preserved floral and faunal remains.

Minnesota

Farley Village (21HU2) series

Wood charcoal and nutshell collected 1989 from the Farley Village Site, Houston County (43°39′42″N, 91°42′12″W) and submitted by J. Gallagher, Mississippi Valley Archaeological Center. The samples date a proto-historic Oneota occupation.

WIS-2173. **200 ± 50**

Sample from Feature 2. $\delta^{13}C = -26.9‰$

WIS-2174. **465 ± 50**

Sample from Feature 19. $\delta^{13}C = -27.2‰$

Nebraska

Upper Blue River Basin (25BU37) series

Wood charcoal collected 1989 from the upper Blue River Basin, Butler County (41°05′N, 97°10′W) by J. Ludwickson and R. Bozell and submitted by R. Bozell, Nebraska State Historical Society. The samples provide an age and phase-level cultural affiliation for Central Plains tradition expansion into the upper Blue River Basin.

WIS-2146. **770 ± 50**

Sample from Feature 8908, remains of a northwest centerpost of house. $\delta^{13}C = -25.1‰$

WIS-2147. **675 ± 50**
$\delta^{13}C = -24.7‰$

Sample from Feature 8904, a trash-filled pit extending 0–72 cm below the house floor.

WIS-2148. **680 ± 50**

Sample from Feature 8909, remains of a southwest centerpost of the house. $\delta^{13}C = -27.4‰$

WIS-2149. **695 ± 50**
$\delta^{13}C = -25.9‰$

Sample from Feature 8921, a trash-filled pit extending 0–125 cm below the house floor.

Lower Platte River Basin (25CC228) series

Wood charcoal collected 1989 from the lower Platte River Basin, Cass County (41°01′N, 96°18′W) by J. Ludwickson and R. Bozell and submitted by R. Bozell. The dates add to the chronology of Nebraska Phase adaptations in the lower Platte River Basin (Blakeslee & Caldwell 1979).

WIS-2150. **660 ± 50**
$\delta^{13}C = -25.6‰$

Sample from Feature 8904, a trash-filled pit extending 0–65 cm below the floor.

WIS-2151. **595 ± 50**

Sample probably from a wall post or roof rafter. $\delta^{13}C = -26.1‰$

Platte and Loup River Basin Uplands (25HL28) series

Wood charcoal collected 1985 from this site, Hall County (40°55′N, 98°41′W) by W. Hunt and submitted by R. Bozell. The dates help determine upland settlement ages.

WIS-2154. **870 ± 40**

Sample probably from a roof rafter or wall post remnant. $\delta^{13}C = -24.8‰$

WIS-2155. **830 ± 50**

Sample probably from a roof rafter or wall post remnant. $\delta^{13}C = -26.0‰$

Lower Platte River Basin (25SY31) series

Wood charcoal collected 1984 from this site, Sarpy County (41°2′N, 96°15′W) by J. Ludwickson and R. Bozell and submitted by R. Bozell. The dates help to separate chronologically the upper from the lower component at this site, and to refine the timing of the Nebraska Phase occupation of the lower Platte Basin (Blakeslee & Caldwell 1979).

WIS-2152. **765 ± 50**

Sample from an activity area above a large Nebraska Phase lodge. $\delta^{13}C = -25.4‰$

WIS-2153. **930 ± 50**

Sample from the floor of a house. $\delta^{13}C = -24.7‰$

Ohio

Petersen (33OT9) series

Wood charcoal collected 1989 from the Petersen Site (42°30′23″N, 83°1′15″W) and submitted by D. Stothers, University of Toledo, Ohio. Dates help determine Indian Hills and Wolf Phases (Stothers & Pratt 1980; Stothers & Graves 1985; Graves 1984; Stothers & Abel 1989).

WIS-2133. **210 ± 50**

Sample from Feature 2, a pit 30–70 cm below surface. $\delta^{13}C = -26.3‰$

WIS-2134. **380 ± 50**

Sample from Feature 34, a pit 25–40 cm below surface. $\delta^{13}C = -26.7‰$

WIS-2135 **240 ± 40**

Sample from Feature 49, a pit 30–40 cm below surface. $\delta^{13}C = -26.2‰$

Wisconsin

Statz (47DA642) series

Wood charcoal collected 1990 from the Statz Site, Dane County (43°12′N,89°29′W) by P. Coutch, P. Ladwig, M. Schlafmann, P. Nepokroeff and S. Brown, and submitted by N. Meinholz and S. Brown, State Historical Society, Madison. The sample was recovered from a semisubterranean structure to date the use of the structure.

WIS-2205. **1060 ± 50**

Sample from Feature 90. $\delta^{13}C = -26.6‰$

WIS-2206. **1010 ± 50**

Sample from Feature 90. $\delta^{13}C = -26.3‰$

WIS-2207. **840 ± 50**

Sample from Feature 128. $\delta^{13}C = -26.4‰$

WIS-2210. **1040 ± 50**

Sample from Feature 134. $\delta^{13}C = -26.7‰$

WIS-2211. **890 ± 50**

Sample from Feature 144. $\delta^{13}C = -27.0‰$

Pike River series

Wood charcoal collected 1990 from the Pike River Site, Kenosha County (42°38′N, 87°49′W) by D. Wasion and submitted by D. Joyce, Kenosha Public Museum. The samples help date the Middle to Late Woodland transition.

WIS-2229. **910 ± 50**

Sample from 11–12 cm below surface. $\delta^{13}C = -26.8‰$

WIS-2230. **1350 ± 50**

Sample from Feature 14, a hearth. $\delta^{13}C = -27.5‰$

Filler (47LC149) series

Wood charcoal collected 1988 and 1989 from the Filler Site, LaCrosse County (43°56′30″N, 91°15′20″W) by J. Paulson, J. Vradenburg, M. O'Malley and P. Becker, and submitted by J. T.

Penman, State Historical Society, Madison. Dates from this site determined that this Oneota occupation was not contemporary to the adjacent Ot Site (Penman 1984) (see below).

WIS-2120. **270 ± 50**

Sample from Feature 1. $\delta^{13}C = -26.3‰$

WIS-2121. **220 ± 50**

Sample from Feature 2. $\delta^{13}C = -25.4‰$

WIS-2122. **230 ± 60**

Sample from Feature 3. $\delta^{13}C = -26.3‰$

WIS-2194. **370 ± 50**

Sample from Feature 61. $\delta^{13}C = -27.1‰$

WIS-2201. **345 ± 55**

Sample from Feature 16. $\delta^{13}C = -25.6‰$

WIS-2202. **260 ± 50**

Sample from Feature 36. $\delta^{13}C = -25.6‰$

WIS-2203. **310 ± 50**

Sample from Feature 47. $\delta^{13}C = -25.9‰$

WIS-2204. **260 ± 50**

Sample from Feature 63. $\delta^{13}C = -26.3‰$

WIS-2114. Firesign (47LC359) **460 ± 50** $\delta^{13}C = -25.9‰$

Wood charcoal collected 1988 from the Firesign Site, LaCrosse County(44°56′N, 91°16′W) by M. O'Malley and submitted by J. T. Penman. This sample dates the latest prehistoric occupation at the Tremaine village complex.

Midway Village (47LC19) series

Wood charcoal collected 1984, 1985, and 1988 from the Midway Village Site, LaCrosse County (43°56′35″N, 91°16′05″W) by R. Boszhardt, J. Gallagher, R. Rodell and A. LaFond, and submitted by R. Boszhardt, Mississippi Valley Archaeological Center. Oneota vessel pieces were also found at the site.

WIS-2107. **300 ± 50**

Sample from Feature 2. $\delta^{13}C = -26.2‰$

WIS-2108. **650 ± 50**

Sample from Feature 89, a pit. $\delta^{13}C = -26.2‰$

WIS-2109. **470 ± 50**

Sample from Feature 222. $\delta^{13}C = -26.1‰$

WIS-2110. **440 ± 50**

Sample from Feature 234, a refuse pit. $\delta^{13}C = -26.9‰$

WIS-2111. **610 ± 50**

Sample from Feature 276, a pit. $\delta^{13}C = -26.0‰$

WIS-2112. **570 ± 50**

Sample from Feature 2, a storage pit. $\delta^{13}C = -21.1‰$

Ot (47LC262) series

Wood charcoal collected 1988 and 1989 from the Ot Site, LaCrosse County (43°56′30″N, 91°15′30″W) by J. O'Gorman, A. Olson, P. Becker and J. Evanson, and submitted by J. T. Penman. A cemetery at this site was dated previously (Broihahn, Penman & Rusch 1987; Steventon & Kutzbach 1988).

WIS-2118. **260 ± 70**

Sample from Feature 19. $\delta^{13}C = -26.5‰$

WIS-2119. **510 ± 50**

Sample from Feature 30. $\delta^{13}C = -26.4‰$

WIS-2184. **210 ± 50**

Sample from Feature 13, a trash pit. $\delta^{13}C = -26.0‰$

WIS-2185. **300 ± 50**

Sample from Feature 31, a trash pit. $\delta^{13}C = -25.4‰$

WIS-2186. **415 ± 50**

Sample from Feature 47. $\delta^{13}C = -26.9‰$

WIS-2187. **270 ± 50**

Sample from Feature 62, a trash pit. $\delta^{13}C = -25.7‰$

WIS-2188. **310 ± 50**

Sample from Feature 82. $\delta^{13}C = -26.1‰$

WIS-2189. **390 ± 50**

Sample from Feature 93.

WIS-2190. **340 ± 50**

Sample from Feature 136. $\delta^{13}C = -26.3‰$

WIS-2192. **350 ± 50**

Sample from Feature 163. $\delta^{13}C = -25.4‰$

WIS-2192. **220 ± 50**

Sample from Feature 172. $\delta^{13}C = -25.5‰$

WIS-2193. **460 ± 50**

Sample from Feature 183. $\delta^{13}C = -26.3‰$

Pammel Creek (47LC61) series

Wood charcoal collected 1989 at the Pammel Creek Site, LaCrosse County (43°45′44″N, 91°12′35″W) and submitted by C. Arzigian, Mississippi Valley Archaeological Center. These samples help date Oneota cultural artifacts and the transitional period between the Brice Prairie Phase and the Valley View Phase.

WIS-2160 **530 ± 50**

Sample from Feature 137, a medium-sized basin, 60 cm deep. $\delta^{13}C = -26.3‰$

WIS-2162. **470 ± 50**

Sample from Feature 139, a basin, 90 cm deep. $\delta^{13}C = -26.2‰$

WIS-2162 **445 ± 50**

Sample from Feature 143, a pit, 60 cm deep. $\delta^{13}C = -26.6‰$

WIS-2163. **570 ± 50**

Sample from Feature 144, a basin, 20 cm deep. $\delta^{13}C = -25.8‰$

WIS-2164. **380 ± 50**

Sample from Feature 156, a pit, 60 cm deep. $\delta^{13}C = -26.6‰$

Tremaine (47LC95) series

Wood charcoal collected 1988 from the Tremaine Site, LaCrosse County(43°56′48″N, 91°15′50″W) by P. Becker, K. Kachel, J. Vradenburg and M. O'Malley, and submitted by J. T. Penman. These samples help date an Oneota occupation.

WIS-2123. **380 ± 50**

Sample from Feature 11. $\delta^{13}C = -26.9‰$

WIS-2124. **1480 ± 50**

Sample from Feature 17. $\delta^{13}C = -25.8‰$

WIS-2125. **450 ± 40**

Sample from Feature 20. $\delta^{13}C = -26.6‰$

WIS-2126. **600 ± 50**

Sample from Feature 32. $\delta^{13}C = -26.7‰$

WIS-2195. **720 ± 50**

Sample from Feature 17. $\delta^{13}C = -25.8‰$

WIS-2113. Cabbage Patch (47OU103) **770 ± 50** $\delta^{13}C = -25.7‰$

Wood charcoal collected 1988 from the Cabbage Patch Site, Outagamie County by B. Workmaster and C. Abrams, and submitted by L. Rusch, Wisconsin State Historical Society. This feature contained Late Woodland pottery types, Point Sauble collared and Madison plain. The sample dates a Late Woodland occupation (Rusch 1988).

Hulburt Creek series

Wood charcoal and charred seeds collected 1990 from the Hulburt Creek Site, Sauk County (43°37′N, 89°50′W) and submitted by W. Gartner, Geography Department, University of Wisconsin–Madison. These samples will help date the construction of ditched field agriculture.

WIS-2214. **980 ± 50**

Sample from 23–27 cm below the planting surface. $\delta^{13}C = -23.0‰$

WIS-2215. **920 ± 50**

Sample from 10–40 cm below the planting surface. $\delta^{13}C = -24.2‰$

Viola Rockshelter (47VE640) series

Wood charcoal collected 1980 and 1986 from the Viola Rockshelter Site, Vernon County (43°28′38″N, 90°41′15″W) and submitted by J. Theler, Mississippi Valley Archaeological Center. Ceramics were recovered from the site.

WIS-2105. **1220 ± 70**

Sample from Feature 3. $\delta^{13}C = -26.5‰$

WIS-2106. **1810 ± 80**

Sample from a test pit. $\delta^{13}C = -26.3‰$

Chile

WIS-2208. San Miguel **450 ± 50** $\delta^{13}C = -23.3‰$

Charcoal ash collected 1990 from San Miguel, Ovalle-Valle Limari, IV Region, Chile (30°0′S, 71°0′W) by M. Biskupovic and submitted by M. Rosado, Rutgers University. The sample corresponds to a settlement site of the Diaguita Classical period.

ECUADOR

WIS-2131. Hacienda Pirincay **2080 ± 60**
$\delta^{13}C = -25.3‰$

Charcoal collected 1988 from Hacienda Pirincay, Canton Paute, Province of Azuay (2°35′S, 78°44′W) and submitted by K. Olsen Bruhns, San Francisco State University. The sample should date the leveling of the site's center and construction of a large pavement, complete with stone-built drains.

PAKISTAN

Harappa series

Wood charcoal collected 1988 and 1989 from Harappa, District Sahiwal, Punjab (30°38′N, 72°52′E) and submitted by J. M. Kenoyer, Anthropology Department, University of Wisconsin-Madison. These dates provide a chronological sequence for the expansion of a proto-urban and subsequent urban settlement at Harappa, Pakistan.

WIS-2139. **3820 ± 60**

Sample from Lot 360, a hearth. $\delta^{13}C=-25.2‰$

WIS-2140. **4290 ± 70**

Sample from Lot 556. $\delta^{13}C = -23.4‰$

WIS-2141. **3920 ± 70**

Sample from Lot 772. $\delta^{13}C = -23.2‰$

WIS-2142 **4135 ± 65**

Sample from Lot 722, Mound E. $\delta^{13}C = -25.6‰$

WIS-2143. **3825 ± 60**

Sample from Lot 798, a hearth. $\delta^{13}C = -26.7‰$

WIS-2144. **3720 ± 100**

Sample from Lot 529. $\delta^{13}C = -26.4‰$

WIS-2145 **4020 ± 60**

Sample from Lot 738. $\delta^{13}C = -25.9‰$

GEOLOGICAL SAMPLES

UNITED STATES

Massachusetts

Great Pond series

A core collected 1989 from Great Pond, Wellfleet, Barnstable County (41°56′25″N, 70°00′03″W) and submitted by M. Winkler, Center for Climatic Research, University of Wisconsin–Madison.

WIS-2129 **1025 ± 50**

Gyttja, 0–10 cm depth. $\delta^{13}C = -25.9‰$

WIS-2130 **2120 ± 60**

Gyttja, 68–79 cm depth. $\delta^{13}C = -26.0‰$

5165 ± 60

WIS-2169. Gull Pond $\delta^{13}C = -24.4‰$

Gyttja, from 72–78 cm below the sediment/water interface was collected from a core October 1989 from Gull Pond, Barnstable County (41°57′17″N,70°00′32″W) by M. Winkler, P. Sanford, K. Hobler, R. Webb, P. Johanson and D. Manski, and submitted by M. Winkler. This date will be used in describing the evolution of Gull Pond. The sample received acid treatment only.

2460 ± 60

WIS-2172. Herring Pond $\delta^{13}C = -30.4‰$

Gyttja, from 171–176 cm below the sediment/water interface was collected with a Livingstone corer October 1989 from Herring Pond, Barnstable County (41°57′46″N, 70°00′49″W) by M. Winkler *et al.* and submitted by M. Winkler. The sample helps provide a chronology for the development of the Gull Pond chain of ponds.

2150 ± 60

WIS-2171. Higgins Pond $\delta^{13}C = -29.2‰$

Gyttja, from 200–206 cm below the sediment/water interface was collected with a Livingstone corer October 1989 from Higgins Pond, Barnstable County (41°57′51″N, 70°00′32″W) by M. Winkler *et al.* and submitted by M. Winkler. The sample helps extend the chronology for the Gull Pond chain.

9500 ± 90

WIS-2170. Williams Pond $\delta^{13}C = -27.1‰$

Gyttja, from 74–82.5 cm depth was collected with a Livingstone corer October 1989 from Williams Pond, Barnstable County (41°57′49″N, 70°00′30″W) by M. Winkler *et al.* and submitted by M. Winkler. The sample dates the beginning of lake sediment deposition during the Late-Glacial/Holocene in Williams Pond.

Minnesota

Elk Lake series

A core collected 1989 from Elk Lake, Grant County (45°52′N, 95°48′W) and submitted by A. Smith, Brown University. These dates, along with pollen analysis, identified a hiatus as mid-Holocene.

WIS-2165 **6470 ± 50**

Sample from 1136–1140 cm below surface. $\delta^{13}C = -17.0‰$

WIS-2166 **6860 ± 70**

Sample from 1126–1132 cm below surface. $\delta^{13}C = -14.5‰$

WIS-2167. **6240 ± 70**

Sample from 1010–1027 cm below surface. $\delta^{13}C = -15.1‰$

WIS-2168. **3590 ± 150**

Sample from 883–893 cm below surface. $\delta^{13}C = -19.6‰$

Montana

WIS-2176. Upper Red Rock Lake

42,800 ± 3450
$\delta^{13}C = -11.5‰$

A core collected 1989 from Upper Red Rock Lake, Beaverhead County (44°36′N, 111°43′W) and submitted by C. Whitlock, Geography Department, University of Oregon. The sample was from 7.12–7.44 m below the water surface.

Pintlar Lake series

A core collected 1989 from Pintlar Lake, Deer Lodge County (45°50′N, 113°40′W) and submitted by C. Whitlock.

WIS-2175. **1795 ± 50**

Gyttja, 6.5–6.6 m below the water surface. $\delta^{13}C = -27.8‰$

WIS-2177. **2130 ± 160**

Gyttja, 8.1–8.2 m depth. $\delta^{13}C = -27.4‰$

WIS-2178. **4120 ± 60**

Gyttja, 9.5–9.6 m depth. $\delta^{13}C = -27.6‰$

WIS-2179. **5830 ± 70**

Gyttja, 11.06–11.18 m depth. $\delta^{13}C = -27.2‰$

WIS-2180. **8220 ± 80**

Gyttja, 12.9–13.0 m depth. $\delta^{13}C = -28.0‰$

WIS-2181. **9860 ± 90**

Gyttja, 13.5–13.6 m depth. $\delta^{13}C = -27.4‰$

WIS-2182. **10,690 ± 100**

Gyttja, 13.7–13.8 m depth. $\delta^{13}C = -27.4‰$

South Dakota

WIS-2213. Ortonville Stone Quarry **42,460 ± 4000**
$\delta^{13}C = -26.2‰$

Wood collected 1989 from Ortonville Quarry, Lac Qui Parle County (45°16′N, 96°24′W) by J. Gilbertson and M. Bratrud, and submitted by J. Gilbertson, South Dakota Geological Society. The date confirms a pre-Late Wisconsin age for overlying till deposited by the glacial River Warren.

Wisconsin

WIS-2159. Long Island **210 ± 50**
$\delta^{13}C = -26.8‰$

Fibric peat collected 1989 at Long Island, Ashland County (46°43′N,90°46′W) by D. Kiesel and submitted by L. Bona, Geology Department, University of Wisconsin–Madison. The sample was from 115–125 cm depth and should give a minimum age of foreshore deposits in the beach ridge (Swain 1981).

Otter Island series

Decomposed sphagnum peat collected 1989 at Otter Island, Apostle National Lakeshore, Ashland County and submitted by A. Swain, Center for Climatic Research, University of Wisconsin–Madison. The samples date the beginning of a decrease of pine and increase of birch, spruce and hemlock in the area.

WIS-2127. **2460 ± 60**

Peat, 50–55 cm below the present peat surface. $\delta^{13}C = -27.4‰$

WIS-2128. **3890 ± 70**

Peat, 75–80 cm below the present peat surface. $\delta^{13}C = -28.1‰$

Chub Lake series

A core collected 1988 from Chub Lake, Dodge County (43°13′N, 88°53′W) and submitted by M. Kolb, Department of Geosciences, University of Wisconsin–Milwaukee. These dates will determine the chronology of Holocene lacustrine deposition in southeastern Wisconsin.

WIS-2222. **13,250 ± 130**

Silty clay, 2 m below the sediment surface. $\delta^{13}C = -22.0‰$

WIS-2223. **12,720 ± 130**

Silty clay, 3 m below the sediment surface. $\delta^{13}C = -20.0‰$

WIS-2224. **14,450 ± 145**

Silty clay, 6 m below the sediment surface. $\delta^{13}C = -18.4‰$

WIS-2132. Hinderman **1270 ± 50** $\delta^{13}C = -25.8‰$

Wood collected 1988 at the Hinderman Site, Grant County (42°39′N, 90°35′W) by J. C. Knox and D. S. Leigh, and submitted by J. C. Knox, University of Wisconsin–Madison. The date records the slow natural rate of floodplain vertical accretion *vs.* human-accelerated accretion (Knox 1985, 1987).

WIS-2209. Pike River **10,320 ± 100** $\delta^{13}C = -26.7‰$

A wood fragment collected 1990 at Pike River Dike Retention Basin, Richland County (43°22′48″N, 90°21′41″W) by P. Cahfer and M. Foreman, and submitted by D. Omernik, USDA Soil Conservation Service. The date is significant in determining the amount of deposition and soil development processes occurring after deposition.

Peru

Laguna Jeronimo series

Lake sediment collected 1987 at Laguna Jeronimo, central Peru (11°47′S, 75°13′W) and submitted by H. E. Wright, Limnological Research, University of Minnesota, Minneapolis. The objective is to date the end of Late-Pleistocene glaciation in the Peruvian Andes (Wright, Seltzer & Hanson 1989.)

WIS-2156. **1900 ± 60**

Organic lake sediment, 895–902.5 cm below the water surface. $\delta^{13}C = -28.2‰$

WIS-2157. **4160 ± 90**

Organic lake sediment, 997.5–1002.5 cm below the water surface. $\delta^{13}C = -25.3‰$

WIS-2158. Laguna Pomacocha **4095 ± 60** $\delta^{13}C = -23.1‰$

Organic lake sediment collected 1987 at Laguna Pomacocha, central Peruvian Andes (11°46′S, 75°16′W) and submitted by H. E. Wright. The sample is from 710–715 cm below the water surface, and is used to date pollen stratigraphy in the Holocene (Wright, Seltzer & Hanson 1989).

REFERENCES

Bender, M. M., Bryson, R. A. and Baerreis, D. A. 1965 University of Wisconsin radiocarbon dates I. *Radiocarbon* 7: 399–407.

Blakeslee, D. and Caldwell, W. 1979 The Nebraska Phase: An Appraisal. *Reprints in Anthropology* 18. Lincoln, Nebraska, J&L Reprint Company.

Broihahn, J. H., Penman, J. T. and Rusch, L. 1987 Transportation archaeology in Wisconsin: The 1986 field season. *Wisconsin Department of Transportation Archaeology Report* 13.

Graves, J. (ms.) 1984 The Indian Hills site (33WO4). Archaeological reflections of a protohistoric assistaeronon town. M.A. thesis, University of Toledo, Ohio.

Knox, J. C. 1985 Responses of floods to Holocene climatic change in the Upper Mississippi Valley. *Quaternary Research* 23: 287–300.

_____1987 Historical valley floor sedimentation in the upper Mississippi Valley. *Annals of the Association of American Geographers* 77: 224–244.

Penman, J. T. 1984 Archaeology of the Great River Road: Summary report. *Wisconsin Department of Transportation, Archaeology Report* 10.

Rusch, L. A. (ms.) 1988 Archaeological test excavations at the Dowser (OU100), Tews (OU102), Cabbage Patch (OU103), and Cleo's (OU104) sites, Outagamie County, Wisconsin. Report on file at the State Historic Preservation Office & State Historical Society of Wisconsin Museum.

Steventon, R. L. and Kutzbach, J. E. 1986 University of Wisconsin radiocarbon dates XXIII. *Radiocarbon* 28(3) 1206–1223.

_____1988 University of Wisconsin radiocarbon dates XXV: *Radiocarbon* 30(3): 367–383.

Stothers, D. and Abel, T. 1989 The position of the "Pearson complex" in the late prehistory of northern Ohio. *Archaeology of Eastern North America*: 192 p.

Stothers, D. and Graves, J. 1985 The Prairie Peninsula co-tradition. *Archaeology of Eastern North America* 13: 153–175.

Stothers, D. and Pratt, G. 1980 Cultural continuity and change in the region of the Western Lake Basin. *Toledo Area Aboriginal Research Bulletin* 9: 1–38.

Swain, A. (ms.) 1981 Final report to the national park service on forest and disturbance history of Apostle Islands. Center for Climatic Research, University of Wisconsin, Madison.

Wright, H. E., Seltzer, G. and Hanson, B. 1989 Glacial and climatic history of the central Peruvian Andes. *National Geographic Research* 5: 439–446.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 155–175]

RUDJER BOŠKOVIĆ INSTITUTE RADIOCARBON MEASUREMENTS XII

DUŠAN SRDOČ, NADA HORVATINČIĆ, INES KRAJCAR BRONIĆ, BOGOMIL OBELIĆ

Rudjer Bošković Institute, P. O. Box 1016, 41001 Zagreb, Croatia

and

ADELA SLIEPČEVIĆ

Faculty of Veterinary Medicine, University of Zagreb

INTRODUCTION

We present here radiocarbon analyses made since our previous list (Srdoč *et al.* 1989). Sample pretreatment, combustion and counting techniques are essentially the same as described previously (Srdoč, Breyer & Sliepčević 1971), supplemented by new techniques for groundwater processing (Srdoč *et al.* 1979). The calculation of ages follows conventional protocol (Stuiver & Polach 1977). These ages can be converted from the 5570-year half-life to the chronometrically more correct half-life of 5730 years by multiplying by the factor, 1.029. Ages and standard deviations of all samples are adjusted for stable isotope fractionation according to the recommendations in Stuiver and Polach (1977), except for groundwater, calcareous deposits and aquatic plants. The $\delta^{13}C$ values of the latter reflect the environmental conditions during their formation or growth rather than fractionation (Mook 1976; Krajcar Bronić *et al.* 1986; Marčenko *et al.* 1989). Thus, any percent modern (pMC) correction based on $\delta^{13}C$ values is meaningless or even misleading. Sample descriptions are prepared in collaboration with collectors and submitters. Calibrated ages were calculated using the program of Stuiver and Reimer (1987).

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ARCHAEOLOGICAL SAMPLES

YUGOSLAVIA

Z-1966. Statue of Christ's head **98.9 ± 0.8 pMC**

Sample is from a wooden statue of Christ's head (43 tree rings), from a private collection. Collected and submitted 1987 by V. Lavrenčič, Ljubljana, Slovenia.

Comment: Calibrated range: AD 1686–1955.

Vela spilja series

Charcoal mixed with clay from Vela spilja cave, Korčula Island, 0.85–1.64 m below ground level, near Vela Luka (48°58′N, 16°44′E), 130 m asl, Croatia. Collected and submitted Dec. 1987 by B. Čečuk, Archaeological Institute, Yugoslav Academy of Sciences and Arts, Zagreb.

Z–1968. **6990 ± 120**

Charcoal from Layer 5 above a grave, 0.85–1.12 m depth.

Z–1967. **7300 ± 120**

Charcoal from Layer 6 above the same grave, 1.12–1.64 m depth.

Comment (B.Č.): This was a systematic archaeological investigation of a Neolithic site. The expected age was ~6000 BP. The date from an earlier measurement was Z-1742: 5430 ± 100 (Srdoč *et al.* 1989: 86).

Ajdovska jama cave series

Charcoal from Ajdovska jama cave at Nemška Vas near Krško (45°58′N, 15°30′E), east Slovenia. Collected by M. Horvat, Faculty of Sciences, Ljubljana and submitted 1987 by A. Šercelj, Slovenian Academy of Sciences and Arts, Ljubljana. Samples from a systematic excavation of a Neolithic site. Dates correspond to earlier measurements, Z-1042 to -1045 (Srdoč *et al.* 1984: 451), Z-1178, -1179, -1554, -1602, -1603 (Srdoč *et al.* 1987: 138–139) and Z-1822, -1860 (Srdoč *et al.* 1989: 86).

Z-2042. Ajdovska jama 41/87 **5230 ± 110**

Charcoal from Quadrant 35. Sample was associated with human bones.

Z-2043. Ajdovska jama 34/87 **4820 ± 100**

Charcoal from a brown loose layer, Quadrant 35.

Z-2044. Ajdovska jama 18/87 **4900 ± 100**

Charcoal from a gray ash layer, Quadrant 35.

Z-2123. Ajdovska jama 42 **5360 ± 130**

Charcoal with charred pollen from a central hall, Quadrant 24, Section 12.

Z-2179. Ajdovska jama 19 **5160 ± 130**

Charcoal with charred pollen from Quadrant 39, Section 68.

Comment (D.S.): Z-1603 is an outlier in this series; Z-1822 is a speleothem whose age agrees well with the charcoal age, if we assume the initial ^{14}C activity, A_0, of speleothems equal to 85 pMC, a pervasive value for A_0 in karst of Dinarides.

Sisak series

Fragments of a charred beam from a building near the Kupa River bank at Sisak (45°30′N, 16°20′E), Croatia. Collected and submitted 1988 by V. Nenadić, Department of Archaeology, Institute of Historical Sciences, University of Zagreb.

Z-2063. Sisak 1 **170 ± 110**

Fragment of a charred beam, 3.85 m depth.

Z-2064. Sisak 2 **20 ± 110**

Fragment of a charred beam, 4.10 m depth.

Comments: (V.N.): Expected age: 250 BP. (D.S.): The expected age is within calibrated range (AD 1675–1955), according to Stuiver and Reimer (1987).

Z-2112. Sisak **1990 ± 120**

Fragment of a wooden beam buried in the Kupa River bed, probably from the foundation of a Roman mint. Collected and submitted 1989 by B. Slovenec and G. Grgić, Sisak.

Z-2065. Podsreda **600 ± 80**

Remnants of a rotten wooden beam built into the south facade of a stone wall in Podsreda (46°2′N, 15°38′E), near Bistrica ob Sotli. Collected and submitted 1988 by B. Uršić, Regional Institute for Protection of Cultural Monuments, Zagreb.

Comment (B.U.): Expected age: Middle Ages (12th or 13th century).

Z-2096. Vladikina ploča **2650 ± 110**

Charcoal from a fireplace in Vladikina ploča cave, Rsovac near Pirot (43°11′26″N, 22°45′17″E), 758 m asl, 20 m from the entrance, covered with 1 to 5-cm-thick calcite flowstone. Collected and submitted 1988 by D. Gavrilović, University of Belgrade.

Comment (D.G.): Expected age: 500 BP. Dates the period of cave occupation. Dates from earlier measurements are Z-1641: 290 ± 100 (Srdoč *et al.* 1989: 85), indicating an extended period of cave occupation.

Brezovica series

Wood fragments from the base of a Roman road at Mala Vas near Brezovica (46°1′N, 14°26′E), 300 m asl, Slovenia. Collected 1988 by T. Bregant, Faculty of Arts and Sciences, Ljubljana and submitted by A. Šercelj.

Z-2098. Mala Vas, VS-10/3 1 **780 ± 80**

Wood fragments (*Fagus*, *Corylus*, *Populus*) from 130–150 cm depth, Quadrant III.

Z-2099. Mala Vas, VS-10/3 2 **580 ± 80**

Wood fragment (*Betula*) from 125 cm depth, Quadrant III.

Comment (A.Š.): Expected age: Roman period.

Z-2113. Plav **>37,000**

Fossil wood (*Juniperus* sp.) from a Pleistocene terrace at Plav (42°35′N, 19°38′E), Montenegro. Collected 1989 by J. Kunaver, Faculty of Arts and Sciences, Ljubljana and submitted by A. Šercelj.

Z-2114. Bukovnica **5650 ± 110**

Charcoal from a Neolithic site, Quadrant 224, Mkv 64–66, 74–76 at Bukovnica near Dobrovnik (45°39′N, 16°22′E), 280–300 m asl, 15 km east of Murska Sobota. Collected 1989 by I. Šavelj, Regional Museum, Murska Sobota and submitted by A. Šercelj.

Comment (I.Š.): Expected age: Neolithic.

Z-2125. Statue of King David's head **200 ± 110**

Sample is from a wooden (oak or walnut) statue of King David's head, from a private collection. Collected and submitted 1989 by I. Krtalić, Zagreb.

Zagreb – Grič series

Charcoal from a fireplace, Clarissa monastery, Grič, Upper Town, Zagreb (45°50′N, 16°0′E), 150 m asl, Croatia. Collected and submitted 1989 by N. Majnarić-Pandžić, Department of Archaeology, University of Zagreb.

Z-2130. Zagreb – Grič 1 **660 ± 120**

Charcoal from Pit S, 180–183 cm depth.

Z-2129. Zagreb – Grič 2 **2050 ± 90**

Charcoal from Fireplace A.

Z-2133. Zagreb – Grič 3 **2810 ± 130**

Charcoal from Trench B2/3, 174.8 cm depth.

Comment (N.M.-P.): Expected age: Middle Ages (15th or 16th century).

Z-2159. Barice **2990 ± 90**

Charcoal from a cremation site in the central part of Tumulus I at Barice near Laminci village, Jaružani (45°6′15′N, 17°22′E), 92 m asl, Bosnia. Collected and submitted 1989 by B. Čović, Sarajevo Museum (Đurdjević 1987).

Comment (B.Č.): The tumulus is characteristic of the newly discovered Barice – Gredjani cultural group. Expected age: 3300–3500 BP.

Z-2156. Kistanje **350 ± 100**

Charcoal from the yard of St. Archangels monastery, on the Krka River bank near Kistanje (43°59′N, 16°0′E), Bukovica, Croatia. Collected and submitted 1989 by B. Uršić, Regional Institute for Protection of Cultural Monuments, Zagreb.

Comment (B.U.): Expected age: AD 9 to 13th century.

Kalnik – Igrišče series

Charcoal from systematic excavations of a Late Bronze Age settlement on Mt. Kalnik, Igrišče (46°05′N, 16°27′E), 400 m asl, north Croatia. Collected and submitted 1989 by N. Majnarić-Pandžić.

Z-2160. Kalnik – Igrišče **2540 ± 60**

Charcoal from Hearth 3.

Z-2163. Kalnik – Igrišče A1 A10 **2890 ± 90**

Charcoal, 0.40 m depth.

Z-2161. Kalnik – Igrišče K1 A9 **2980 ± 70**

Charcoal, 0.59 m depth.

Z-2162. Kalnik – Igrišče K1 B8 **2650 ± 60**

Charcoal, 1.20 m depth

Comment (N.M.-P.): Expected age: 13th to 11th century BC.

Slavonska Požega series

Wood, bones and charcoal from Sv. Lovro medieval church in Slavonska Požega (45°20′N, 17°41′E), Slavonia, Croatia (Langhamer 1966; Degmedžić 1977; Horvat & Mirnik 1977). Samples were dated to determine the beginning of church construction. Collected and submitted 1989 by I. Srša, Croatian Institute for Restoration, Zagreb.

Z-2168. Slavonska Požega 1 **560 ± 80**

Wooden scaffolding from inside the western gable. An earlier measurement was Z-1921: 790 ± 100 (Srdoč *et al.* 1989: 86–87).

Comment (I.Š.): Expected age: 700 BP.

Z-2169. Slavonska Požega 2 **700 ± 90**

Wooden beam, part of western gable.

Comment (I.Š.): Expected age: 700 BP.

Z-2171. Slavonska Požega 3 **400 ± 90**

Charred wood from the roof or floor, buried in soil at 0.40 m depth.

Comment (I.Š.): Expected age: 500–550 BP.

Z-2172. Slavonska Požega 4 **280 ± 80**

Wood fragments of a coffin from Trench 8, Grave C.

Comment (I.Š.): Expected age: 200–450 BP.

Z-2175. Slavonska Požega 6 **270 ± 80**

Human bones in soil from Trench 2, Grave 2f.

Comment (I.Š.): Expected age: maximum 700 BP.

Z-2176. Slavonska Požega 7 **320 ± 60**

Human bones from a stone-walled grave, Trench 4.

Comment (I.Š.): Expected age: 500 BP.

Z-2174. Slavonska Požega 8 **370 ± 80**

Wooden beam from the northern wall in the aisle.

Z-2170. Slavonska Požega 9 **690 ± 80**

Wooden beam from the eastern gable.

Comment (I.Š.): Expected age: 700 BP.

Z-2177. Slavonska Požega 10 **110 ± 80**

Human bones from Grave C.

Stari grad series

Fragments of charred wood from an ancient Greek settlement near Stari grad (43°10′N, 16°36′E), Hvar Island, Croatia. Collected and submitted 1989 by J. Jelčić, Institute for Preservation of Cultural Monuments, Split. Samples were dated to determine the time of destruction of this settlement.

Z-2178. Stari Grad 1 **2540 ± 70**

Fragments of charred wood from a Hellenistic house yard, 2 m depth.

Z-2183. Stari Grad 2 **1330 ± 80**

Fragments of charred wood in front of St. John's Early Christian Church.

Z-2181. Zadar **800 ± 80**

Wooden fragments covered with mortar from an arch in a crypt, Sv. Stošija Cathedral, Zadar (45°07′N, 15°15′E), south Croatia. Collected and submitted 1989 by M. Domijan, Institute for Preservation of Cultural Monuments, Zadar.

Comment (M.D.): Expected age: Middle Ages.

Nova Rača series

Human bones from Nova Rača church near Bjelovar (45°47′N, 16°56′E), 175 m asl, central Croatia. Collected and submitted 1989 by G. Jakovljević, Bjelovar Museum. Samples were dated to determine the chronology of the strata containing human bones.

Z-2184. Nova Rača **380 ± 60**

Bones buried in clay, 1.81 m below the church sacristy.

Z-2187. Nova Rača **610 ± 60**

Bones at 1.20 m below ground level from a necropolis outside the church, near the south wall.

Z-2255. Nova Rača **80 ± 80**

Bones from Grave 1 in the churchyard, 110 cm depth.

Z-2256. Nova Rača **70 ± 80**

Bones from Grave 2 in the churchyard, 87 cm depth.

Z-2258. Nova Rača **470 ± 70**

Bones from plundered Grave 2, below the church sacristy, 100 cm depth.

Z-2260. Nova Rača **570 ± 80**

Bones from plundered Grave 18, below the church sacristy, 30 cm depth.

Comments: (G.J.): Expected age: Middle Ages. (G.J.): Date confirms results of archaeological and historical investigations.

Grabovac series

Samples of charcoal from Eneolithic pits, from Grabovac brickyard near Đakovo (45°18′N, 18°27′E). Collected 1990 by I. Pavlović, Regional Museum Đakovo, and submitted by S. Forenbacher, Department of Archaeology, University of Zagreb.

Z–2239. **4760 ± 150**

Charcoal from Pit 4.

Z–2240. **4250 ± 150**

Charcoal from Pit 3B.

Comment (I.P.): Expected age: coeval with the Baden culture (Durman & Obelić 1989).

Vinkovci series

Charcoal from the floor of a primitive Vučedol-type house near Vinkovci (45°16′N, 18°49′E), ≈20 km west of Eneolithic site, Vučedol, east Croatia. Collected 1977 and submitted 1990 by A. Durman, Department of Archaeology, University of Zagreb. Samples were dated to determine the duration of the Vučedol culture in this area. Dates correspond to earlier measurements, Z-1817, -1818 (Srdoč *et al.* 1989: 87).

Z-2189. Vinkovci, Sample A **3940 ± 90**

Charcoal.

Z-2190. Vinkovci, Sample B **4080 ± 130**

Charcoal.

Z-2238. Krapina **1320 ± 140**

Fragments of fossil oak from the Krapina River bed near Zaprešić (45°48′N, 15°58′E), Croatia. Collected 1989 and submitted 1990 by D. Stošić.

Z-1926. Koprivnički bregi **4470 ± 140**

Charcoal mixed with soil from Pit DE/87 at Seče near Koprivnički bregi (46°10′N, 14°34′E), Koprivnica, Croatia. Collected and submitted 1987 by Z. Marković, Koprivnica Town Museum.

Comment (Z.M.): Expected age: 3000–4000 BC.

HUNGARY

Gorzsa series

Charcoal from tell-type Late Neolithic settlements from the Tisza region, southeast Hungary (Horvath, 1982, 1986, 1987; Benkö *et al.* 1989). Collected by F. Horvath, Mora Ferenc Museum, Szeged, and submitted 1987 by L. Benkö, Institute of Isotopes, Hungarian Academy of Sciences, Budapest.

Z-2007. Tápé - Lebö 1 **5870 ± 110**

Charcoal from Block I, Layer 2–3, Quadrant 4/A at Tápé - Lebö (46°16′N, 20°17′E), 82 m asl.

Z-2008. Szegvar - Tuszkoves 2 **6550 ± 160**

Charcoal from Block I, Layer 29, Quadrant 105 at Szegvar - Tuszkoves (46°36′53″N, 20°15′42″E), 87 m asl.

Z-2009. Gorzsa 3 **5610 ± 110**

Charcoal from Block XIV, Layer 6–7, Phase 6 at Gorzsa (46°16′25″N, 20°17′26″E), 81 m asl.

Z-2010. Gorzsa 4 **5820 ± 110**

Charcoal from Block VI, House 2, Phase C at Gorzsa.

Z-2011. Gorzsa 5 **5890 ± 110**

Charcoal from Block XVIII, Layers 24–25, Phase D at Gorzsa.

Comment (D.S.): Dates are discussed in Benkö *et al.* (1989).

HYDROGEOLOGICAL AND GROUNDWATER SAMPLES

YUGOSLAVIA

Ljubljansko barje series

Groundwater from Ljubljansko barje peat bog (45°58′N, 14°32′E), Slovenia. Groundwater issues from a confined limestone aquifer. The total dissolved inorganic carbon (TDIC) consists predominantly of Ca-bicarbonate. Collected by J. Prestor and submitted 1988 by M. Veselič, Geological Institute, Ljubljana, Slovenia. This groundwater was studied in relation to a potable waterworks.

Z-2027. P-2 **21.1 ± 1.3 pMC**

Groundwater. Tritium activity: <0.2 Bq/liter.

Z-2028. Ž-4 **76.1 ± 1.4 pMC**

Groundwater. Tritium activity: 3.3 ± 0.2 Bq/liter.

Z-2029. V-3 **23.4 ± 1.1 pMC**

Groundwater. Tritium activity: <0.2 Bq/liter.

Bačka series

Samples were part of a hydrogeological and hydrodynamic study of groundwater from subartesian water-bearing horizons with intergranular porosity Bačka, Vojvodina. Collected and submitted 1988 by M. Lazarević, "Jaroslav Černi" Institute, Belgrade.

Z-2030. Savino Selo 1 **74.2 ± 1.1 pMC**

Groundwater from a phreatic well, 206.4 m deep, at Savino Selo (45°30'N, 19°33'E), 36.06–61.35 m depth (pH = 7.5, HCO_3 = 481 mg/liter).

Z-2031. Titov Vrbas 2 **7.0 ± 0.8 pMC**

Spring water supplying Titov Vrbas waterworks (45°34'N, 19°37'E), 121.60–144.70 m depth. Subartesian aquifer 156 m deep (pH = 7.7, HCO_3 = 518 mg/liter).

Z-2032. Kumra 3 **4.4 ± 0.8 pMC**

Groundwater from a subartesian well, 220 m deep, at Kumra, 185.00–198.50 m depth.

Z-2033. Zmajevo 4 **2.8 ± 0.8 pMC**

Artesian mineral water from a well, 369.80 m deep, at Zmajevo (45°27'N, 19°42'E), 348.90–367.90 m depth.

Z-2034. Bački Jarak 5 **1.9 ± 0.8 pMC**

Water from a subartesian well at Bački Jarak (45°22'N, 19°53'E), 158.16–181.50 m depth.

Z-2035. Bački Jarak 6 **6.4 ± 0.8 pMC**

Water from a subartesian well at Bački Jarak, 130 m deep, 90–123 m depth.

Surdulica series

Water, peat, soil and plants from Surdulica, one of the largest geothermal systems in southeast Yugoslavia, Mt. Besna kobila massif, 1922 m asl, part of the geotectonic region of Serbia and Macedonia (Milovanović *et al.* 1989). The hydrogeothermal system is in the neogen-fissured granodiorite aquifer, surrounded by crystalline schists. The system produces cold water (~100 liter/s, alkalinity 61–140 mg/liter) and geothermal water (~70 liter/s, alkalinity 260–267 mg/liter). This series is part of an investigation of the mechanism of water formation in the Surdulica geothermal system. Collected and submitted 1988 by M. Hadžišehović, Institute Boris Kidrič, Belgrade.

Z-2066. Kula BK-6 **38.8 ± 1.3 pMC**

Water from a borehole, 112 m deep, at Kula near Kriva Feja (42°34'N, 22°09'E), 1354 m asl, Mt. Besna kobila.

Z-2073. Bujanovac BH-7 1 **3.3 ± 0.8 pMC**

Geothermal water (43°C, pH = 6–6.5) from Borehole BH-7, 556 m deep, at Bujanovac (42°25'N, 21°45'E), 410 m asl, south Serbia. Collected 12–15 July 1988.

Z-2137. Bujanovac BH-7 2 **6.9 ± 0.8 pMC**

Groundwater from Borehole BH-7. Collected 20–25 May 1989.

Z-2074. Valjavica 22 **67.0 ± 1.1 pMC**

Water from the Valjavica well (13°C, pH = 5.5) near Surdulica (42°40′N, 22°10′E), 910 m asl, south Serbia.

Z-2135. Tolovački potok **61.3 ± 1.0 pMC**

Water from the Tolovac catchment near Vranjska Banja spa (42°30′N, 21°48′E), 577 m asl, Mt. Besna kobila.

Z-2136. Vranjska Banja V6-3 **4.8 ± 0.8 pMC**

Geothermal water (67°C) from a borehole, 450 m deep, at Vranjska Banja spa (42°30′N, 21°48′E), 406 m asl.

Z-2134. Ribarska Banja RB-5 **11.1 ± 0.9 pMC**

Geothermal water (40°–52°C) from Ribarska Banja spa (43°24′N, 21°31′E), 430 m asl, Mt. Jastrebac foothills.

Z-2138. Toplac **21.0 ± 0.9 pMC**

Geothermal water (20.5°–24°C) from Toplac (42°33′N, 21°57′E), 393 m asl.

Z-2067. Ladne Vode ML-1 **2.6 ± 0.8 pMC**

Water from a borehole, Mlava River valley near Gornjačka klisura (42°45′N, 20°25′E), southeast Serbia.

Z-2071. Ždrelo 11 **104.1 ± 1.2 pMC**

Water from a spring (pH = 6) at Ždrelo village near Petrovac (44°18′N, 21°32′E), 710 m asl, on the Mlava River.

Z-2072. Stari Glog 1 **94.1 ± 1.5 pMC**

Water (17.6°C, pH = 5.5–6) from a catchment at Stari Glog (42°28′N, 22°08′E), 710 m asl, Mt. Besna kobila.

Velenje series

Groundwater from several boreholes in brown coal (lignite) at Velenje coal mine (46°21′N, 15°07′E), Slovenia. Collected and submitted 1988 by M. Veselič, Geological Institute Ljubljana. This was part of an investigation of the origin of groundwater flooding the coal mine.

Z-2075. VAS-3 **2.2 ± 0.9 pMC**

Groundwater from Borehole VAS-3. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = -5.2‰$

Z-2076. VAS-4 **15.3 ± 1.4 pMC**

Groundwater from Borehole VAS-4. Tritium activity: 0.6 ± 0.2 Bq/liter. $\delta^{13}C = -7.9‰$

Z-2077. VAS-5 **13.1 ± 1.1 pMC**

Groundwater from Borehole VAS-5. Tritium activity: 0.6 ± 0.2 Bq/liter. $\delta^{13}C = -8.6‰$

Z-2078. VL-16 **0.0 ± 0.8 pMC**

Groundwater from Borehole VAS-16. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = 0.6‰$

Z-2079. VAS-6 **13.9 ± 1.0 pMC**

Groundwater from Borehole VAS-6. Tritium activity: 0.5 ± 0.2 Bq/liter. $\delta^{13}C = -8.6‰$

Z-2080. VAS-7 **5.9 ± 1.3 pMC**

Groundwater from Borehole VAS-7. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = -8.9‰$

Z-2081. VL-15 **2.2 ± 0.8 pMC**

Groundwater from Borehole VL-15. Tritium activity: <0.2 Bq/liter.

Z-2082. VL-18 **26.0 ± 1.0 pMC**

Groundwater from Borehole VL-18. Tritium activity: 0.8 ± 0.2 Bq/liter. $\delta^{13}C = -11.2‰$

Z-2083. VS-17 **8.0 ± 0.8 pMC**

Groundwater from Borehole VS-17. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = -19.1‰$

Z-2084. VS-19 **6.7 ± 0.8 pMC**

Groundwater from Borehole VS-19. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = -15.9‰$

Z-2085. VA-21 **42.5 ± 1.1 pMC**

Groundwater from Borehole VA-21. Tritium activity: 2.2 ± 0.2 Bq/liter. $\delta^{13}C = -11.7‰$

Z-2086. VS-20 **5.6 ± 0.8 pMC**

Groundwater from Borehole VS-20. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = -18.2‰$

Z-2087. VA-22 **30.3 ± 0.9 pMC**

Groundwater from Borehole VA-22. Tritium activity: 1.0 ± 0.2 Bq/liter. $\delta^{13}C = -11.8‰$

Z-2088. VS-23 **30.8 ± 1.2 pMC**

Groundwater. Tritium activity: <0.2 Bq/liter. $\delta^{13}C = -13.6‰$

General Comment: Tritium activity in waters with relatively low ^{14}C activity indicates mixing of old and recent water, and the age of these waters cannot be determined on the basis of their ^{14}C content.

Niška Banja series

Thermomineral waters from Niška Banja spa (43°18′N, 22°01′E) near Niš, Serbia. Collected and submitted 1988 by M. Milivojević, Faculty of Mineralogy, Geology and Petrology Engineering, University of Belgrade. This was a hydrogeological investigation of the origin of thermomineral water in a low-temperature system of Niška Banja spa.

Z-2101. Glavno vrelo **49.7 ± 1.2 pMC**

Water from Glavno vrelo (main spring). Tritium activity: 0.7 ± 0.1 Bq/liter.

Z-2102. Suva Banja **51.2 ± 1.3 pMC**

Water from Suva Banja spa. Tritium activity: 0.7 ± 0.2 Bq/liter.

Z-2103. IEBNB-1 **14.6 ± 1.1 pMC**

Water from borehole IEBNB-1, 520 m depth, 210 m asl.

Z-2104. GC-3 **3.0 ± 0.8 pMC**

Mineral water from a 370-m-deep borehole, 150 m depth, 250 m asl, at Gornje Crniljevo near Osečina (19°40′N, 44°29′E), west Serbia. Water was dated in a hydrogeological investigation of the origin of the mineral water and the possibility of exploration. Tritium activity: <0.2 Bq/liter.

Czechoslovakia

Czechoslovakia series

Groundwater samples from central Bohemian Karst and Mt. Male Karpaty, west Slovakia. Collected and submitted 1987 by N. Horvatinčić and J. Šilar, Faculty of Science, Charles University, Praha, Czechoslovakia. Dating of recent tufa helps determine the initial ^{14}C activity of groundwater.

Z-1972. Cisarska Rokle **78.7 ± 1.2 pMC**

Water from a spring at Cisarska Rokle, near Srbsko (49°52′N, 17°02′E), 310 m asl. Tritium activity: 4.7 Bq/liter.

Z-1973. Koda **87.1 ± 1.1 pMC**

Water from a catchment at Koda, near Srbsko (49°52′N, 17°02′E), 320 m asl. Tritium activity: 5.7 Bq/liter.

Z-1974. Babina **76.4 ± 1.1 pMC**

Water from a catchment at Babina, near Hradište pod Vratnom, Mt. Male Karpaty (48°33′N, 17°30′E). Tritium activity: 1.7 Bq/liter.

Z-1975. Sv. Jan pod Skalou **82.8 ± 1.1 pMC**

Water from a spring at Sv. Jan pod Skalou (49°53′N, 17°02′E). Tritium activity: 5.5 Bq/liter.

GEOLOGICAL SAMPLES

YUGOSLAVIA

Bačka series

Fossil soil was collected from boreholes in Bačka, Vojvodina for geotectonic investigations in northeast Serbia. Collected and submitted Sep. 1987 by M. Galečić, Geological Institute Belgrade.

Z-1952. Mali Beograd **$33,800 \begin{smallmatrix} +3200 \\ -2300 \end{smallmatrix}$**

Fossil soil from Borehole BT-39, E-71129 at Mali Beograd (45°53′N, 19°40′E), 107 m asl, 1030 cm depth.

Z-1953. Dušanovo **>37,000**

Fossil soil from Borehole BT-48, E-71129 at Dušanovo (45°54′N, 19°46′E), 95 m asl, 790 cm depth.

Z-1954. Gunaroš **26,700 ± 2000**

Fossil soil from Borehole BT-53, E-71153 at Gunaroš (45°46′ N, 19°50′ N), 100 m asl, 960 cm depth.

Z-1955. Mileševo **29,900 ± 2600**

Fossil soil from Borehole BT-54, E-71167 at Mileševo (45°44′N, 19°48′E), 104 m asl, 890 cm depth.

Z-1956. Mileševo

Fossil soil from Borehole BT-55, E-71162 at Mileševo (97 m asl), 915 cm depth.

Serbia series

Clay and peat were collected from Serbia in an investigation of the Quaternary of Serbia, and dated to draft a geological map of Yugoslavia. Collected and submitted 1987 by M. Rakić, Geozavod, Belgrade.

Z-1988. Radinac 079-4-2 4 **Modern**
106.3 ± 1.2 pMC

Gray clay, 0.4 m below moor vegetation from an old bed of the Velika Morava River at Radinac, near Smederevo (44°39′N, 20°55′E), 72 m asl.

Z-1989. Zvečka 078-3-4 17 **7250 ± 170**

Organogenic pond clay with fauna from an old meander of the Sava River at Zvečka village near Obrenovac (44°38′N, 20°10′E), 73 m asl, at depth 1.0–1.5 m below ground, covered by reeds and cultivated land.

Comment: Expected age: 4000–6000.

Z-1990. Zabrežje 078-3-2 35 **95.3 ± 1.2 pMC**

Aleurite with humus at Zabrežje village near Obrenovac (44°41′N, 20°05′E), 72 m asl, at depth 2.0 m, below cultivated land.

Comment: 680 ± 110.

Z-1991. Gaj 080-1-4 69 **11,220 ± 250**

Peat from an old meander of the Danube River at Gaj village, near Kovin (44°48′N, 21°02′E), 67 m asl, Banat, Vojvodina, at depth 1.0–1.5 m, below cultivated land.

Comment (M.R.): Expected age: 4000–6000.

Z-1992. Dubovac 080-1-4 70 **2750 ± 130**

Sandy peat from an old meander of the Danube River at Dubovac village (44°48′N, 21°10′E), 69 m asl, Banat, Vojvodina, from the surface.

Comment (M.R.): Expected age: 4000–6000.

Lake Bled series

Lake Bled (46°21′N, 14°08′E), 500 m asl. Collected and submitted 1988 by J. Pezdič, Institute Jožef Štefan, Ljubljana, as part of a sedimentological investigation of the origin of the lake marl. The lake marl consists of calcite without detrital minerals. $\delta^{13}C$ ranges between −1.03 and −2.36‰ *vs.* PDB.

Z-1993. B-K-2 **24.8 ± 0.9 pMC**

Lake sediment, 40 cm depth.

Z-1994. B-83 **75.4 ± 0.6 pMC**

Shells from the base of the lake, 2 m depth.

Z-1995. B-11/2 **23.6 ± 0.9 pMC**

Lake sediment, 0–10 cm depth.

Z-1996. B-11/2 **19.6 ± 0.8 pMC**

Lake sediment, 20–30 cm depth.

Z-1997. B-11/2 **26.2 ± 0.9 pMC**

Lake sediment, 50–60 cm depth.

Z-1998. B-11/5 **37.3 ± 0.9 pMC**

Lake sediment, 20–30 cm depth.

Z-1999. B-I-28 **17.3 ± 0.9 pMC**

Lake sediment, 5–20 cm depth.

Z-2001. B-I-28 **14.7 ± 0.8 pMC**

Lake sediment, 20–50 cm depth.

Z-1969. Selca **8820 ± 210**

Clay rich in organic material (humus), from a borehole core at 150 cm depth, from Selca, near Škofja Loka (45°13′10″N, 14°13′25″E), 430 m asl, Slovenia. Collected and submitted 1988 by A. Šercelj. Sample was dated for a vegetation profile.

Comment (A.Š.): Expected period: Holocene.

Kamniške Alpe series

Samples were dated in a lithostratigraphic investigation of alpine karst. Collected 1987 by J. Urbanc and submitted 1988 by J. Pezdič.

Z-2002. Kamniška jama cave **220 ± 80**

Humus from Kamniška jama cave (46°21′N, 14°31′E), 1100 m asl.

Z-2003. Ogrlice 2 **Modern 105.2 ± 1.2 pMC**

Topsoil at Ogrlice (46°20′N, 14°40′E), 0–15 cm depth.

Z-2004. Bela 3 **Modern 103.9 ± 1.3 pMC**

Topsoil at Bela (46°20′N, 14°37′E), 0–15 cm depth.

Z-2005. Ljubljansko barje **2800 ± 130**

Fragments of wood from Ljubljansko barje peat bog (45°59′N, 14°32′E). Collected by J. Urbanc and submitted 1988 by J. Pezdič, as part of a palynological investigation of Ljubljansko barje peat bog.

Surdulica series

This investigation was of ^{14}C activity of peat, soil and plants in the recharge area of the Surdulica aquifer. Collected and submitted 1988 by M. Hadžišehović.

Z-2068. Lake Vlasina **Modern 111.4 ± 1.5 pMC**

Peat from Lake Vlasina shore (42°42′N, 22°20′E), 1300 m asl, southeast Serbia.

Comment (M.H.): Expected age: Holocene.

Z-2069. Lake Vlasina **Modern 126.1 ± 1.4 pMC**

Soil mixed with grass from a clearing near Lake Vlasina (42°42′N, 22°20′E) 1295–1300 m asl, Mt. Besna kobila.

Z-2070. Lake Vlasina — **Modern 123.9 ± 1.5 pMC**

Various unidentified plants from the Lake Vlasina area.

Comment: Result is close to the atmospheric ^{14}C activity.

Z-2089. Unije Island 51-4-J — **5700 ± 150**

Loess concretions (loess kindchen) from Unije Island (44°35′N, 14°18′E), 9 m asl, Adriatic Sea, Croatia. Collected for a stratigraphic and sedimentologic investigation. Collected and submitted 1988 by Z. Velimirović, INA-Project, Zagreb.

Z-2097. Sesalac cave — **64.4 ± 1.1 pMC**

Speleothem deposited on a wall of the main shaft of a short tunnel, Sesalac cave near Soko Banja (43°41′53″N, 21°59′26″E), 602 m asl, Serbia. Sample was dated to determine the time of gravel filling (Petrović 1984). Collected and submitted 1987 by D. Gavrilović, Faculty of Natural Sciences and Mathematics, Belgrade.

Comments (D.G.): Expected age: Pleistocene. (D.S.): assuming A_o = 100 pMC, the speleothem ^{14}C age is 3500 ± 140 BP.

Rijeka series

Organic fraction from Boreholes A-2 and S-2 at Rijeka (45°18′N, 14°25′E), southwest Croatia. Collected and submitted 1987 and 1989 by E. Pavlovec, Institute for Civil Engineering, Rijeka. Collected for geotechnical investigations of the city development area.

Z-2036. Rijeka — **6410 ± 160**

Organic mud from Borehole A-2, 8 m depth.

Z-2105. 1 — **3680 ± 140**

Organic fraction of soil, 25 m depth.

Z-2106. 2 — **1330 ± 120**

Organic fraction of soil, 5.7 m depth.

Comment: Expected age: Holocene.

Lake Kozjak series

Samples of calcareous lake sediment from the Plitvice Lakes (44°50′N, 15°35′E) central Croatia were collected with a hand corer February 1989 by scuba diver, D. Petricioli, Center for Marine Research, Rudjer Bošković Institute, Zagreb.

TABLE 1. Lake Kozjak Sediment Core

Sample no.	Depth (cm)	pMC	Age (BP)	$\delta^{13}C$‰ (PDB)
Z-2116	5–10	79.9 ± 0.6	Modern	−8.6
Z-2117	10–15	74.0 ± 0.6	214 ± 70	−8.9
Z-2118	15–20	74.4 ± 0.6	170 ± 70	−9.1
Z-2119	20–25	73.6 ± 0.8	260 ± 90	−9.2
Z-2120	25–29	73.3 ± 0.8	290 ± 90	−9.1

Z-2127. Lake Kozjak **82.1 ± 1.0 pMC**

The organic part of the sediment was used to date the organic residue after chemical pretreatment of samples Z-2117, -2119 and -2120.

Comment: Initial ^{14}C activity, A_0 = 76%, was determined by two independent methods (Srdoč *et al.* 1986b; Krajcar Bronić *et al.* 1992). Table 1 shows the results.

Plitvice travertines series

Travertine from the Plitvice Lakes (44°50'N, 15°35'E) central Croatia. Collected and submitted 1989 by H. Chafetz, Department of Geosciences, University of Houston, D. Srdoč and N. Horvatinčić.

Z-2142. Plitvički Ljeskovac **0.0 ± 0.5 pMC**

Compact crystalline flowstone from old travertine barrier near Plitvički Ljeskovac.

Z-2143. Smolčića cave **1.7 ± 0.5 pMC**

Compact, hard, partly porous travertine above Smolčića cave.

Z-2144. Bijela rijeka **1.4 ± 0.6 pMC**

Crystalline flowstone from an inactive travertine barrier above Bijela rijeka brook.

General Comment (D.S.): Samples were collected for U/Th analysis. The ^{14}C content indicates the degree of contamination with recent carbonates.

Z-2124. Rovinj **9270 ± 250**

Peat from a borehole in marine sediment, 98–108 cm depth, at station 109 in the North Adriatic Sea near Rovinj (45°05'N, 13°37'E). Collected and submitted 1989 by S. Puškarić, Center for Marine Research, Rudjer Bošković Institute, Zagreb.

Krka River series

Tufa from Krka River near Skradin (43°49'N, 15°55'E), Croatia. Collected and submitted 1989 by D. Srdoč, N. Horvatinčić, S. Golubić, Boston University and A. Plenković, University of Zagreb, and 1991 by D. Srdoč and T. Bjedov, Elektroprojekt, Zagreb.

Z-2253. 1 **76.1 ± 0.8 pMC**

Recent tufa near Roški slap waterfall.

Z-2254. 2 **79.7 ± 0.8 pMC**

Recent tufa near Roški slap waterfall, downstream from Z-2253.

Z-2264. 3 **81.7 ± 0.8 pMC**

Recent tufa, Lake Mlinarsko.

Z-2141. 4 **83.1 ± 0.8 pMC**

Recent tufa from a barrier, surface layer, downstream from Lake Mlinarsko.

Z-2139. 5 **93.0 ± 0.8 pMC**

Recent tufa, Skradinski buk waterfall.

Z-2262. 6 **95.8 ± 0.8 pMC**

Recent tufa, Skradinski buk waterfall.

Z-2140. 7 **95.9 ± 0.8 pMC**

Recent tufa, Skradinski buk waterfall.

Comment (D.S.): Measurements were of recent tufa activity in the Krka River, north Dalmatia, Croatia. ^{14}C activity of dissolved inorganic carbon (DIC) increases downstream due to the exchange with more active atmospheric CO_2 (Srdoč *et al.* 1986a). Recent tufa precipitated from DIC reflects the DIC ^{14}C activity. We observed an increase of 10% in ^{14}C activity over a 12-km-long stretch between locations, Roški slap and Skradinski buk.

Z-2251. Kalića kuk 1 **1.7 ± 0.8 pMC**

Old tufa barrier, presently 10–15 m above the lake surface. Hard, compact tufa from the top of the barrier.

Z-2252. Kalića kuk 2 **3.0 ± 0.8 pMC**

Hard, very porous tufa from the top of the barrier.

Z-2250. Kalića kuk 3 **2.5 ± 0.8 pMC**

Hard, porous tufa from a niche dug in the barrier, ≈2 m above the lake surface.

Comment (D.S.): ^{14}C activity of old, preglacial tufa reflects the contamination with recent carbonates, not the age of the samples.

Z-2323. Manojlovac waterfall **75.8 ± 0.8 pMC**

Tufa crust on limestone.

Z-2324. Manojlovac water mill **75.7 ± 0.8 pMC**

Tufa crust on wood.

Comment (D.S.): Samples Z-2323 and -2324 were collected in a dry riverbed. This section of the Krka River was diverted in 1908 into a hydroelectric power plant; hence, the samples reflect pre-bomb ^{14}C activity.

Varaždinske Toplice series

Tufa from the thermal Varaždinske Toplice spa (46°10′N, 16°25′E), Croatia. Collected and submitted 1989 by D. Srdoč, N. Horvatinčić and H. Chafetz.

Z-2147. 1 **0.7 ± 0.8 pMC**

Calcareous deposit on cooling tower walls. $\delta^{13}C = 0.4‰$

Z-2149. 2 **2.9 ± 0.5 pMC**

Tufa from the bottom of Gradišće cave. $\delta^{13}C = -1.1‰$

Z-2155. 3 **0.5 ± 0.6 pMC**

Recent tufa from a spring. $\delta^{13}C = 0.8‰$

Z-2157. 4 **0.0 pMC**

Tufa from an old barrier near Sv. Duh chapel. $\delta^{13}C = -2.1‰$

Z-2158. 5 **5.3 ± 0.4 pMC**

Tufa deposit covering Roman ruins. $\delta^{13}C = 0.7‰$

Comment (D.S.): $\delta^{13}C$ values indicate a non-biogenic origin of the tufa. ^{14}C activity is due to contamination with recent carbonates.

Z-2148. 076-4-2(49-1) **5730 ± 110**

Alluvial-proluvial sediment southwest of Šabac (44°47′N, 19°39′E), Serbia, collected and submitted 1989 by M. Rakić, Geological Institute, Belgrade, for drafting a geological map of Yugoslavia.

Baška series

Charcoal fragments in clayey sandy gravel near Baška (44°59′N, 14°45′E), Krk Island, Croatia. Collected and submitted 1989 by L. Marjanac, INA Project, Zagreb.

Comment: Expected age: Middle Pleistocene. Samples were dated to interpret paleofacies.

Z-2150. Baška 1-XXV-6-1 **5130 ± 300**

Organic soil, 8 m asl.

Z-2151. Baška 3-XXIV-6-1 **25,610 ± 2640**

Organic soil, 8 m asl.

Z-2153. Baška 117/2-6 **24,790 ± 790**

Organic soil, 10 m asl.

Z-2152. Karojba **98.3 ± 0.9 pMC**

Fragment of driftwood near Karojba (45°18′N, 13°49′E), Istria, west Croatia. Collected 1989 by S. Puškarić and submitted by M. Mihovilović, Istarski boksiti, Rovinj.

Z-2166. Krupa River **45.3 ± 0.7 pMC**

Tufa covering the bed of the Krupa River (44°11′N, 15°54′E), Bukovica, south Croatia. Collected and submitted 1989 by D. Srdoč, N. Horvatinčić and H. Chafetz.

Z-2167. Krčić **56.0 ± 0.7 pMC**

Tufa from Krčić brook waterfall, downstream from Krčić village (44°01′N, 16°18′E) near Knin, south Croatia. Collected and submitted by D. Srdoč and H. Chafetz.

Z-2180. Pag 5-VI-7-K **>37,000**

Organic soil from Pag Island (44°26′N, 15°04′E). Collected and submitted 1989 by L. Marjanac.

UNITED STATES

Z-2191. White Bluff **91.6 ± 0.8 pMC**

Recent tufa from White Bluff, Texas. Collected and submitted 1990 by H. Chafetz.

Comment: Sample was dated to determine the initial ^{14}C activity.

CZECHOSLOVAKIA

Czechoslovakia series

Tufa samples from central Bohemian Karst and Mt. Male Karpaty, west Slovakia were dated to determine initial ^{14}C activity. Collected and submitted 1987 by N. Horvatinčić and J. Šilar.

Z-2115. Koda **99.6 ± 1.2 pMC**

Recent tufa covered by aquatic moss (*Cratoneurum commutatum*) from Koda valley near Srbsko (49°50′N, 14°15′E), 320 m asl.

Z-1979. Koda **91.9 ± 1.3 pMC**

Recent tufa, 300 m downstream, at Koda near Srbsko. $\delta^{13}C = -9.0 \pm 0.4‰$

Z-1976. Cisarska Rokle **81.8 ± 1.2 pMC**
$\delta^{13}C = -9.3 \pm 0.4‰$

Recent tufa, 150 m downstream from a lower eroded cascade at Cisarska Rokle (49°52′N, 17°02′E).

Z-1977. Cisarska Rokle **89.2 ± 1.2 pMC**
$\delta^{13}C = -7.1 \pm 0.4‰$

Recent tufa, 300 m downstream from a lower eroded cascade at Cisarska Rokle.

Z-1978. Cisarska Rokle **46.1 ± 0.9 pMC**

Tufa from a lower eroded cascade, on a bank near the waterfall.

Z-1980. Hradište pod Vratnom **0.1 ± 0.6 pMC**

Old tufa from a quarry at Hradište pod Vratnom, Mt. Male Karpaty (49°00′N, 17°25′E).

Z-1981. Sv. Jan pod Skalou 8 **46.1 ± 0.9 pMC**

Dark gray tufa from Sv. Jan pod Skalou (49°53′N, 17°02′E).

Z-1982. Sv. Jan pod Skalou 9 **57.0 ± 1.0 pMC**

Yellowish porous tufa.

Z-1983. Sv. Jan pod Skalou 10 **52.2 ± 0.9 pMC**

Porous tufa with clay particles.

Z-1984. Sv. Jan pod Skalou 11 **51.9 ± 0.9 pMC**

Yellowish porous tufa, 30 cm above Sample 10.

REFERENCES

Benkö, L., Horvath, F., Horvatinčić, N. and Obelić, B. 1989 Radiocarbon and thermoluminescence dating of prehistoric sites in Hungary and Yugoslavia. *In* Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 992–1002.

Degmedžić, J. 1977 The Frankopans and the Sv. Lovro church. *In* Strbašić, M., ed., *Požega, 1227–1977.* Zagreb, Grafički zavod Hrvatske: 158–160 (in Croatian).

Durman, A. and Obelić, B. 1989 Radiocarbon dating of the Vučedol culture complex. *In* Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 1003–1009.

Đurdjević, M. 1987 Barice/Laminci. Ljubljana, *Arheološki pregled* 1986: 50–51 (in Slovenian).

Horvat, Z. and Mirnik, I. 1977 The Middle Age architecture of the Požega Valley. *In* Strbašić, M., ed., *Požega, 1227–1977.* Zagreb, Grafički zavod Hrvatske: 121–157. (in Croatian)

Horvath, F. 1982 The Late Neolithic stratum of the Gorsza tell. *Archaeologiai Ertesitö* 109: 201–222.

_____1986 Aspects of Late Neolithic changes in the Tisza region. *Beri Balogh Adám Múzeum Evkönyve* 13: 89–102.

_____1987 Hádmezövásárhely-Gorsza. A settlement of the Tisza culture. *In* Tálas, L., Raczky, P., Bökönyi, S., Kalicz, N., Selmeczy, L., Trogmayer, O. and Kelemen, E., eds., *The Late Neolithic of the Tisza Region.* Budapest-Szolnok: 31–46.

Krajcar Bronić, I., Horvatinčić, N., Srdoč, D. and Obelić, B. 1986 On the initial ^{14}C activity in karst aquifers with short mean residence time. *In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2A): 436–440.

_____1992 Experimental determination of the ^{14}C initial activity of calcareous deposits. *In* Long, A. and Kra, R. S., eds., Proceedings of the 14th International ^{14}C Conference. *Radiocarbon*, in press.

Langhamer, J. 1966 The chronology of Sv. Lovro church. *Požeški zbornik II*, Ogranak Matice hrvatske, Slavonska Požega: 149–171 (in Croatian).

Marčenko, E., Srdoč, D., Golubić, S., Pezdič, J. and Head, M. J. 1989 Carbon uptake in aquatic plants deduced from their natural ^{13}C and ^{14}C content. *In* Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 785–794.

Milovanović, B., Stanković, S., Komatina, M., Hadžišehović, M., Župančić, M., Miljević, N., Stepić, R. and Obelić, B. 1989 Isotopic investigation of the Surdulica geothermal system. *In* Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 893–901.

Mook, W. G. 1976 The dissolution-exchange model for dating groundwater with ^{14}C. Interpretation of environmental isotope and hydrochemical data. *Groundwater Hydrology.* Vienna, IAEA: 213–225.

Petrović, D. 1984 Sesalačka pećina cave. Beograd, *Zbornik radova Instituta za geografiju* 31: 9–18 (in Serbian).

Srdoč, D., Breyer, B. and Sliepčević, A. 1971 Rudjer Bošković Institute radiocarbon measurements I. *Radiocarbon* 13(1): 135–140.

Srdoč, D., Krajcar Bronić, I., Horvatinčić, N. and Obelić, B. 1986a Increase of ^{14}C activity of dissolved inorganic carbon along a river course. *In* Stuiver, M. and Kra, R. S., eds, Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2A): 515–521.

Srdoč, D., Obelić, B., Horvatinčić, N., Krajcar Bronić, I., Marčenko, E., Merkt, J., Wong, H. K. and Sliepčević, A. 1986b Radiocarbon dating of lake sediment from two karst lakes in Yugoslavia. *In* Stuiver, M. and Kra, R. S., eds, Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2A): 495–502.

Srdoč, D., Obelić, B., Horvatinčić, N., Krajcar Bronić, I. and Sliepčević, A. 1984 Rudjer Bošković Institute radiocarbon measurements VIII. *Radiocarbon* 26(3): 449–460.

_____1989 Rudjer Bošković Institute radiocarbon measurements XI. *Radiocarbon* 31(1): 85–98.

Srdoč, D., Obelić, B., Sliepčević, A., Krajcar Bronić, I. and Horvatinčić, N. 1987 Rudjer Bošković Institute radiocarbon measurements X. *Radiocarbon* 29(1): 135–147.

Srdoč, D., Sliepčević, A. Obelić, B. and Horvatinčić, N. 1979 Rudjer Bošković Institute radiocarbon measurements V. *Radiocarbon* 21(1): 131–137.

Stuiver, M. and Polach, H. A. 1977 Discussion: Reporting of ^{14}C data. *Radiocarbon* 19(3): 355–363.

Stuiver, M. and Reimer, P. J. 1987 User's guide to the programs CALIB and DISPLAY Rev 2.1: Quaternary Isotope Laboratory, University of Washington.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 177–185]

INSTRUCTIONS TO AUTHORS

GENERAL GUIDELINES

RADIOCARBON is an international journal published three times a year in the United States. The editors ask contributors to use simple, straightforward language. We prefer the active rather than the passive voice and encourage the use of "I" or "we" in manuscripts. We also use American spellings rather than British and ask foreign contributors to consult with English-language experts before submitting their manuscripts. All manuscripts, including date lists, pass peer review before acceptance.

Manuscripts should generally follow recommendations in "Suggestions to Authors of the Reports of the United States Geological Survey," 6th edition, 1978, Superintendent of Documents, Government Printing Office, Washington, DC 20402. A new edition, which may be printed soon, will be the preferred guide for *RADIOCARBON* manuscripts. For a guide to bibliographic citations, see "Bibliographic Guide for Editors and Authors," 1974, The American Chemical Society, Washington, DC 20036. Unfortunately, 1974 is the latest edition of this useful manual. For general writing, an excellent reference is the 13th edition of "The Chicago Manual of Style," The University of Chicago Press. For Geosciences, we recommend "Writing in Earth Science" by Robert L. Bates, 1988, American Geological Institute, Alexandria, Virginia. We also use "Webster's New Collegiate Dictionary." Reprints of this latest Style Guide are available upon request from the Managing Editor.

We accept manuscripts in triplicate with a cover letter that includes the author's telephone number, Fax number, E-mail address and/or Telex number. All copy, including the abstract, figure captions, acknowledgments and references, must be double spaced, and printed on one side of the paper. Leave adequate margins (minimum size 1" or 2.5 cm) on each edge of the paper and at least 1.5" or 4 cm on the top and bottom. Use *only one* space after a period (full stop) at the end of a sentence, and periods after initials and abbreviations. Number all pages including the references, tables and figures. Do not submit a floppy diskette with a research article or report until you submit the final revised manuscript. Also include one hard copy along with the digital form of the final manuscript. However, date lists, or, *e.g.*, letters to the editor, should be submitted initially on diskette. We prefer WordPerfect 5.1 in IBM format, but we also will accept Microsoft Word and Wordstar in IBM-compatible MS DOS. Please convert text written in other word-processing programs or on other formats (*e.g.*, Macintosh, CP/M) to ASCII, and designate format. We can accommodate either 3.5" (720 kb or 1.44 mb) or 5.25" (360 kb or 1.2 mb) diskettes. We can also download text from E-mail.

SECTIONS OF THE JOURNAL

Regular issues contain several sections:

1. Research Articles or Reports (for organization, see below)
2. Date Lists (for organization, see below)
3. Notes and Comments, Letters to the Editor, Discussions
4. Radiocarbon Updates – news of interest to the radiocarbon community
5. Laboratories (generally at the end of each volume)
6. Book Reviews
7. Announcements – advertisements, publications, meetings, job openings

Reporting ^{14}C dates

We will continue to report ^{14}C ages in years BP (Before Present) without the word, "years." [*Example*: 2750 ± 50 BP]. AD/BC dates or calendric estimates are reported only in conjunction with calibrated ranges. In this instance, use the most recent calibration curves and cite (as of this printing, *RADIOCARBON*, 1986, Vol. 28(2B); a new Calibration Issue is forthcoming in 1992). Designate calibrated ages "cal" [*Examples:* cal AD 1230; 3270 cal BC]. We use BP, AD, BC as symbols, rather than abbreviations, and thus, do not use periods (full stops) with them.

SI units

"SI" is an abbreviation for Le Système International d'Unités, an international system of units adopted by many national and international authorities, associations, professional societies and agencies. Inevitably, a few other, non-SI, units have come into use, which leads to controversy and difference among standards. We strongly favor the use of SI units and adhere to this unified system as much as possible. However, we find no single, authoritative list of units and abbreviations that completely satisfies our needs. We draw from three lists that seem to be the most comprehensive: "Standard for Metric Practice" 1976 American Society for Testing and Materials; "Quantification in Science: The VNR Dictionary of Engineering Units and Measures" by M. Melaragno 1991, Van Nostrand Reinhold, New York; and "Guide for the Use of the International System of Units" by Arthur O. McCoubrey 1991, NIST Special Publication 811.

Unit symbols should be printed in roman type, leaving a space between the number and unit. Unit symbols are not followed by a period, but, when used as an adjective, require a hyphen. [*Examples*: 5 m, *not* 5m; 5-m depth]. No space separates the numerical value and symbols for degree, degree Celsius, %, ‰, minute and second of plane angle. [*Examples:* 10°, 10°C, 15%, −25‰, 35′45″]. No space separates a prefix and a symbol. [*Example:* kiloyear = ka]. Symbols, not abbreviations should follow numerical values. [*Example:* 5 ka, *not* 5000 yr]. A short list of preferred symbols follows:

Unit	Symbol	Unit	Symbol
ampere	A	micro	μ
centimeter	cm	milligram	mg
day	d	milliliter	ml
degree Celsius	°C	millimeter	mm
electron volt	eV	million (giga)	M
gram	g	minute	min
hour	h	mole	mol
kelvin	K	second	s
kilogram	kg	sievert	Sv
liter	liter	thousand (kilo)	k
meter	m	year	a or yr[1]

[1]We continue to use the abbreviation, yr, in some cases, depending on the general context.

ORGANIZATION OF A MANUSCRIPT

Arrange research articles or reports to include the following sections:

1. **TITLE** – boldface capitals at the left margin – avoid abbreviations [Times Roman 10 pt.]
2. *AUTHOR(S)* – italic capitals at the left margin – full first name or two initials with spaces between and periods (full stops) after initials. [*Example: AUSTIN LONG and R. S. KRA*]
3. Affiliation(s) – roman caps and lower case at the left margin – addresses should be complete, including zip or country code numbers. Add USA for the United States. Use numbered footnotes for more than two addresses, or change of address. [*Example:* [1]Present address: Department of Geosciences, The University of Arizona, Tucson, Arizona 85721 USA [8 pt.]]. For more details, see below.
4. **ABSTRACT.** – boldface small caps [8 pt.] at the left margin. Text begins on the same line, double spaced – a concise summary (*ca.* 200 words), containing objectives, methods and results.
5. **INTRODUCTION** – boldface caps [10 pt. initial cap; 8 pt. for the rest] at the left margin
6. **METHODOLOGY or DESCRIPTIVE BACKGROUND** – all headings are at the left margin
7. **RESULTS or DISCUSSION**
8. **CONCLUSIONS**
9. **ACKNOWLEDGMENTS** – should be brief
10. **REFERENCES** – at the left margin [8 pt] – see new style below
11. TABLES – initial cap, small caps following at the top left margin of the table. We prefer camera-ready copy, *after* our editing. For details, see below.
12. Figures – with separate captions [8 pt]. For details, see below.

TEXTUAL ELEMENTS

HEADINGS – as above (Introduction, *etc.*)

Subheading 1 – boldface initial capitals, at the left margin

Subheading 2 – italics, at the left margin, with a period (full stop) and text following.

Subheading 3 – indented italics, with a period and text following.

Paragraphs – block style, not indented.

Running Heads – these appear at the top of each page (after the title page). The righthand, odd-numbered page bears a summary of the title. Authors should check these carefully for meaning and clarity. The lefthand, even-numbered folio bears the authors' names.

Footnotes – avoid if possible, but when necessary, cite with superscripts in Arabic numerals in the text and at the bottom of the same page. Footnote an author's address in the same manner, using consecutive numbers for more than two affiliations, *e.g.*, G. T. Cook[1], D. D. Harkness[2], B. F. Miller[2], E. M. Scott[3], M. S. Baxter[1] and T. C. Aitchison[3]. For footnotes to tables, see below.

Equations – center and leave ample space above and below. Use roman, *not* italic symbols. For complex equations, use the Equation Function of your software program. Number equations, enclosing the number in parentheses at the right margin. Use punctuation (*e.g.*, a period) at the end of the sentence or paragraph. Do *not* use punctuation (*e.g.*, a colon) preceding the equation.

Tables – must show numbers and titles at the top left margin of the table. Use the Table or Column Function of your software program, or separate columns with tabs. *Do not use the space* *bar to separate items in the table*. Clearly mark columnar headings, using initial caps and lower case lettering. Avoid double spacing within the table. Do *not* use ditto marks. For footnotes, place the appropriate symbol, in superscript, to the right of the item to be noted. Place footnotes at the bottom of the table (even if it extends beyond one page) and cite in order (from left to right, top to bottom) in the following sequence: *; **; †; ‡; §; ‖; #. We prefer to receive tables in camera-ready form *after* the editing process (so that we can give you explicit instructions). Identify all tables in the text, so that we know where to place them.

Figures – original line drawings, glossies, laser prints or half-tones. Good-quality graphics may be included on the diskette, along with the final manuscript. We can make a laser print of your figures if they are in WordPerfect 5.1. The quality of the end-product depends directly on the illustration that the author provides. Figures should be reduced as much as possible, not exceeding 5.5" × 7.5" (*ca.* 14 cm × 19 cm) to conform to the page size of the journal. Figures must have captions, numbered consecutively with Arabic numerals. Place figure captions on a separate page, *not* with the figure, unless, of course, they are on the diskette. Provide a key or explain all symbols that appear in the figure, denoting the symbol on the figure or in the caption. Do *not* identify symbols in the text. Identify all figures in the text, so that we know where to place them. Write out the word "Figure" when it is part of the sentence (*e.g.*, Figure 1 shows...) and abbreviate it when it is in parentheses (*e.g.*, (Fig. 1)). Designate multiple parts of a figure with capital letters (*e.g.*, Fig. 1A, 1B). Clearly identify illustrations (by taping a piece of paper to the bottom) with author's name and figure number. Use gloss-coated paper for laser prints. We reserve the right to reduce figures in order to save space, when possible, without compromising legibility. Some papers necessitate the use of reprinted figures (*e.g.*, a history or overview of a particular subject). In such a case, we ask the author to request permission to reprint the figure or table from the publisher, and usually the author(s) as well. We will provide you with a form for this purpose.

Measurements – always use SI or metric units (see above). Use English units only in parentheses, in combination with metric units. Numerical values used in conjunction with units should be in Arabic (*e.g.,* 25 cm). Spell out numbers up through ten when unaccompanied by units of measurement. [*Example:* The procedure lasted eight days, *but,* The procedure lasted 18 d]. For more than one number in a series, use Arabic numbers, with an en dash (–), *not* a hyphen (-). [*Example:* The procedure takes 8–10 d.] Do not join numbers in a range with an en dash; write out prepositions and conjunctions. [*Example*: The procedure takes between 8 and 10 d.]

Isotope numbers – precede symbols in superscript (*e.g.*, ^{14}C, ^{36}Cl). We encourage the use of ^{14}C in the text. It is acceptable to begin a sentence with ^{14}C.

Symbols, abbreviations, acronyms and Greek letters – clearly define abbreviations or acronyms at their first appearance in the text [*Example:* Accelerator Mass Spectrometry (AMS); one standard deviation (1 σ)]. Use symbols, such as >, <, ≅ with Arabic numerals. For more details, see SI Units, above. We use "*ca.*" or ~ with numerals, but "about" or "approximately" with words [*Example:* The procedure lasted approximately eight days]. Other abbreviations that we use often include: *i.e., e.g., vs., et al.* (all in italics and with periods).

CITATION OF PUBLICATIONS IN TEXT

Cite all references in the text and in the reference section at the end of the paper. Textual citations should give the author(s) and date with no punctuation between them. Place the citation within parentheses, unless the authors are part of the sentence [*Examples*: (Kalin & Long 1989); Kalin and Long (1989) described...]. A page, table or figure number should follow a colon, after a space [*Example:* Kalin & Long: 6]. We use the ampersand character (&) within parentheses, but not in the text. Cite the names of 1–3 authors and use *et al.* for more than 3 authors [*Examples:* (Taylor, Long & Kra 1992); (Bard *et al.* 1990)]. Separate two or more references by semicolons [*Example:* (Kalin & Long 1989; Bard *et al.* 1990)]. Cite several works by the same author by date only, separated by commas [*Example:* (Trumbore 1988, 1992)]. Repeat multiple citations; do not use *op. cit.* or *ibid.* We allow the author(s) to determine the order (alphabetical or chronological) for multiple references in the text.

Cite data from notes or observations with dates, if known, or as (ms.) in the text, and use the proper citation in the references (see below). Cite an unpublished manuscript (*e.g.*, a doctoral dissertation) with the year in the text. Refer to a personal communication in the text, *not* in the references. Include the date of the communication whenever possible at the end of the citation. [*Example:* W. S. Broecker, personal communication 1991]

REFERENCES

Place all textual citations in the reference section at the end of the manuscript. Material not cited in the text should not appear in the references. List all authors in the references; do not use *et al.* We require *full* titles of articles and inclusive pages. We do *not* cite references by number. Use initials (with periods) instead of first names in the references. We no longer abbreviate journal titles. For each reference entry, use the hanging indent function of your software program (*e.g.*, in WordPerfect 5.1, press →**Indent** (F4), then ←**Margin Release** (Shift-Tab), and type the entry without hard returns, tabs or multiple spaces.

Arrange citations alphabetically by author's last name. A single-author entry comes before a multiauthor entry beginning with the same name. *Example*:

Stuiver, M. 1982 A high-precision calibration of the AD radiocarbon time scale. *Radiocarbon* 24(1): 1–26.
Stuiver, M. and Pearson, G. W. 1986 High-precision calibration of the radiocarbon time scale, AD 1950–500 BC. *In* Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2B): 805–838.

In entries with the same first author, alphabetize by second author, *etc.* For more than one reference by the same author, cite the oldest publication first. Two or more works by the same author in the same year are distinguished by letters after the date. *Example:*

Switsur, R. 1990a A consideration of some basic ideas for quality assurance in radiocarbon dating. *Radiocarbon* 32(3): 342–346.
_____1990b Statistical quality control graphs in radiocarbon dating. *Radiocarbon* 32(3): 347–354.

A five-character dash indicates multiple references by the same author. The second and following lines of references should start under the sixth character of the author's name. *Example*:

Long, A. and Kra, R. S., eds. 1989 Proceedings of the 13th International ^{14}C Conference. *Radiocarbon* 31(3): 229–1082.
_____1992 Proceedings of the 14th International ^{14}C Conference. *Radiocarbon* 34(3): 000–000.

Do not use the extended dash when coauthors follow the first author. *Example:*

Hedges, R. E. M. 1992 Sample treatment strategies in radiocarbon dating. *In* Taylor, R. E., Long, A. and Kra, R. S., eds., *Radiocarbon After Four Decades: An Interdisciplinary Perspective.* New York, Springer-Verlag: 165–183.
Hedges, R. E. M. and Law, I. A. 1989 The radiocarbon dating of bone. *Applied Geochemistry* 4: 249–253.

Following is our new reference format for:

1. Article in a periodical:

Author's surname, initials of given name, year of publication (no commas before or after), title. *Name of periodical* (in italics or underlined) volume(number): inclusive pages. *Example*:

Vogel, J. S., Nelson, D. E. and Southon, J. R. 1989 Accuracy and precision in dating microgram carbon samples. *Radiocarbon* 31(2): 145–149.

2. Book citation:

Same as above for authors and year. Italicize and capitalize title of book. City of publication, publisher: number of pages. *Example*:

Broecker, W. S. and Peng, T.-H. 1982 *Tracers in the Sea*. Palisades, New York, Eldigio Press: 690 p.

3. Article in edited Proceedings:

The citation should follow the examples of Stuiver and Pearson, above.

If an organization is considered the author of an entry, list the organization as author. *Example:*

International Study Group 1982 An inter-laboratory comparison of radiocarbon measurements in tree-rings. *Nature* 298: 619–623.

Works "in press" must actually be in press, *i.e.*, accepted by a journal. "In press" should follow the citation if the date of publication is known. If date of publication is not known, "in press," set off by commas, should replace the date. *Examples*:

van der Plicht, J. 1992 The Groningen radiocarbon calibration program. *Radiocarbon* 34, in press.
Punning, J.-M. and Rajamae, R., in press, Radiocarbon dates of organic detritus and their possible application to the study of ice dynamics. *Radiocarbon*.

If an author confidently expects to publish a manuscript before the galley proof is returned, he/she may use blank page numbers (000-000). Place (ms.) after the authors for a manuscript that has been submitted but is not yet accepted. *Example*:

Trumbore, S. (ms.) Radiocarbon measurements and soil carbon turnover rates. Submitted to *Ecological Applications*.

Cite an unpublished manuscript, such as a doctoral dissertation, in the same manner, and include the date after (ms.) Do not use italics for an unpublished manuscript. *Example*:

Roeleveld, W. (ms.) 1974 The Groningen coastal area. Ph.D. dissertation, Amsterdam: 252 p.

For a manuscript in preparation, give as much information as possible. *Example:*

Becker, B. (ms.) An 11,000-year German oak and pine dendrochronology for radiocarbon calibration. In preparation.

For a paper that was presented at a conference but not published, give the author, (ms.), year, title, site and date of the conference. *Example*:

Barnhill, J. L., Jull, A. J. T., Lange, T. and Donahue, D. J. (ms.) 1991 Methods for dating of Oriental textiles by accelerator mass spectrometry. Paper presented at the 14th International ^{14}C Conference, Tucson, Arizona, 20–24 May.

Book reviews

Book reviews should not exceed two pages and should bear headings as follows:

The Environmental Record in Glaciers and Ice Sheets. Edited by Hans Oeschger and C. C. Langway, Jr. Report of the Dahlem Workshop, Berlin, 13–18 March 1988. Chichester 1989 John Wiley & Sons, 400 pages.

The reviewer should sign the review at the lower righthand corner and give his/her full affiliation.

Special issues

The length of a manuscript in a regular issue is unrestricted, but may not exceed 12 printed pages (*ca.* 600–700 words per page, including *ca.* 4 figures and 2 tables) in Conference Proceedings. The Editors, Associate Editors and outside referees read all papers, and judge them on scientific merit and relevance to the journal. Presentation of a volunteer paper at a conference will not guarantee publication in the Proceedings issue. If the publication of an accepted manuscript is delayed, we will place it in the next available regular issue. The editors will consider for publication only those manuscripts submitted in proper format by the conference deadline. Workshop Proceedings, whether or not associated with an International Radiocarbon Conference, may appear in a Special Issue. Discussions, *i.e.,* questions and answers following a session, or communications about an article, may be appended to papers. Proceedings follow the general program schedule of the conference or workshop. Other Special Issues include, *e.g.,* the Calibration Issue.

The publication process

The following scenario describes the *RADIOCARBON* publication process: An author submits a manuscript to the *RADIOCARBON* office. We acknowledge receipt of the manuscript, schedule it for a particular issue and select one or two reviewers. We consider the relevance of each review, augment it if necessary, and return the edited manuscript to the corresponding author, along with the reviewers' comments. The corresponding (usually the senior) author prepares the final, revised version of the manuscript, adhering to the recommendations of the editors and reviewers, and returns it to the *RADIOCARBON* office, along with a diskette and original figures. We then prepare galley proofs directly from the diskette, size and make prints of the figures and send the proofs to the author for final checking. We enclose an offprint order form along with the proofs. The author carefully marks corrections in red and returns the order form (even if no offprints are wanted), proofs and manuscript to *RADIOCARBON* within three days. We then prepare a camera-ready copy of the issue, and send it, along with mailing labels and an offprint order form, to the printer (press), who prints, binds and mails the books. We cannot estimate, with a high degree of certainty, the duration of this process, as numerous factors and variables may affect any aspect of publication.

Deadlines

Generally, we adhere to the following schedule:

For	Date
No. 1	Sept 1
No. 2	Jan 1
No. 3	May 1

Date Lists

In general, the format of the date list should follow the style shown in the most recent issue of *RADIOCARBON*. Entries should be brief and precise, yet informative and easily understood by the general reader as well as by the specialist. A *Comment* or *General Comment* should follow every sample or series description, in which the submitter(s) of the sample(s) discuss(es) the significance of the result. Authors should make liberal reference to published literature. When this is not available, it is the responsibility of the dating laboratory to collect the pertinent facts, by requiring the submitter to provide them in publishable form. We encourage the use of maps, tables and figures to fully describe the location of sites, the provenience and comprehensive data surrounding the sample(s). Authors should also describe, in some detail, the methods of collection, storage, sample pretreatment and measurement that they have used. Also, we would like to know the standards, protocol for quality assurance and the calibration program that the laboratory uses.

For geochemical measurements, the accepted standards are:

1. 0.95 times the age-corrected (to AD 1950) activity of NBS Oxalic Acid I ($\delta^{13}C = -19.0‰$)
2. 0.7459 times the age-corrected activity of Oxalic Acid II ($\delta^{13}C = -25‰$); see Stuiver (1983) *Radiocarbon* 25(2): 793.

Report geochemical measurements as per cent of modern carbon (pMC), but where $^{13}C/^{12}C$ assays are available or reasonably assumed, we recommend the Δ notation. See Stuiver and Polach (1977) *Radiocarbon* 19(3): 355–363 for further discussion. List values of $\delta^{13}C$ when known. Laboratories should retain records of $\delta^{14}C$ values in accessible form, whether or not they are published in the original entries.

Dates should be expressed in years BP (before AD 1950). Report calendar estimates and ranges in the *Comment* as cal AD/BC, citing the specific calibration curve and program used to calculate the estimate. We recommend using the curves and programs in the Calibration Issue (1986) and the forthcoming calibrations and program in 1992. Always cite the laboratory number, *e.g.*, A-1320, when referring to a date in the same list or another publication. If the date has been published previously, give the reference.

Title, authors and affiliations are the same as for general articles. Date lists need no abstracts; they start with an introduction and acknowledgments. Divide date lists into sections, *e.g.*, **ARCHAEOLOGICAL SAMPLES**. Further subdivide dates under geographic headings, *e.g.*, *UNITED STATES, Illinois, etc.* Each sample should have a descriptive name, usually that of the locality of collection, and preferably, a name different from those of all other samples. Each description, for a series or a single sample, should include the following: Laboratory number, descriptive name, date expressed in years BP (all in **boldface**), $\delta^{13}C$ value (in *italics*), sample material, with identification information, if relevant, specific location, including stratigraphic provenience, geographic coordinates, collecter and submitter, with dates and affiliation, *Comment(s)* and/or *General Comment. Example:*

9750 ± 70
ISGS-1264. Mauvaise Terre Creek paleochannel, MVT 1B $\delta^{13}C = -28.1‰$

Primarily uncarbonized, nonconiferous (diffuse porous and ring porous) wood and bark, some herbaceous plant debris, 4.67–4.80 m below ground surface in the Illinois Valley; near the base of a stratified and laminated silt unit filling an old meander channel of Mauvaise Terre Creek, incised into the Keach School Terrace; from Scott County, 5 km southwest of Oxville (39°40′50″N, 90° 37′00″W). Collected 1983 by D. S. Leigh; submitted by E. R. Hajic, D. S. Leigh and D. L. Asch.

Comment: This date provides a minimum age for the Keach School Terrace. See Hajic (1987).

Some specific guidelines follow:

- In a series title, the word, "series," is lower case. Indent sample numbers under the series heading.
- Be as specific as possible when identifying the sample material. Use the Linnaean name in parenthesis following the popular name, if the sample is a plant or animal fossil. Include the name of the person who identified the sample. Italicize species names, but not the word, "species" or "sp.".
- Give the precise geographic location, including latitude-longitude coordinates, in parentheses. Do not use Lat and Long; use N, E, S, W, *e.g.*, (39°40′50″N, 90°15′50″W), leaving no spaces between units. National Grid References (NGR) should also be included in parentheses.
- Describe occurrence and stratigraphic postion (but not stratigraphic sequences), including depth or elevation, or cultural association, including period or name of culture, in precise terms. Explain interpretations of stratigraphic or cultural associations in the *Comment*.
- Use decimals, *e.g.*, 5.5 km from the coast.
- Leave a space between number and measurement unit, *e.g.*, 32 cm, not 32cm.
- *Comment*: usually compares the date with other relevant dates, for which the author should provide sample numbers and references. Interpretive material, summarizing the significance of the ^{14}C measurement belongs here, as do technical matters, *e.g.*, chemical pretreatment, special laboratory difficulties, *etc.* Include calendar estimates and calibration information here. We cannot overstate the importance of this section, for it is here that the author should describe the significance of the date.
- *General Comment:* usually deals with a series or group of related samples. Include initials in parentheses before the colon for both *Comment* and *General Comment.* Both start at the left margin. Capitalize the first letter of the first word after the colon. See example, above.
- We have discontinued the abbreviated style with which we have been associated for so long.

In recent issues, we have been publishing site-specific interpretive literature on ^{14}C dating of a particular area or site. These papers represent combinations of research articles and date lists (comprising results from several laboratories) that carefully analyze and explore the ramifications of ^{14}C results. Prepared by consumers rather than producers of ^{14}C dates, these articles are extremely valuable for a wide range of scientific disciplines, and we encourage contributions of this nature. The following are examples:

Erlandson, J., Walser, R., Maxwell, H., Bigelow, N., Cook, J., Lively, R., Adkins, C., Dodson, D., Higgs, A. and Wilber, J. 1991 Two early sites of Eastern Beringia: Context and chronology in Alaskan interior archaeology. *Radiocarbon* 33(1): 35–50.

Kirch, P. V., Flenley, J. R. and Steadman, D. W. 1991 A radiocarbon chronology for human-induced environmental change on Mangaia, Southern Cook Islands, Polynesia. *Radiocarbon* 33(3): 317–328.

Mead, J. I. and Agenbroad, L. D. 1992 Isotope dating of Pleistocene dung deposits from the Colorado Plateau, Arizona and Utah. *Radiocarbon*, this issue.

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 187]

RADIOCARBON UPDATES

New Directors

Rainer Grün is the new director of the Radiocarbon Dating Research Unit at the Australian National University, Canberra. Sometime in the near future, the laboratory will extend research interests to other Quaternary dating techniques, TL and ESR in particular. John Head remains effectively in charge of the radiocarbon operation.

The new Director of the Radiocarbon Laboratory at the University of Wisconsin–Madison (WIS) is Dr. David M. McJunkin. The same address and numbers apply.

Conference Announcement

The Austrian Society for Liquid Scintillation Spectrometry announces an International Conference on Advances in Liquid Scintillation Spectrometry, "LSC 92", 14–18 September 1992 in Vienna, Austria. Abstracts (4 copies) are due 31 March 1992. For more information, contact:

Franz Schönhofer
Austrian Society for Liquid Scintillation Spectrometry
c/o Federal Institute for Food Control and Research
Kinderspitalgasse 15 — Tel: 43 1 40491 520
A-1090 Vienna — Fax: 43 1 40491 540
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Workshop Cancellation

A Workshop on "Variation of Cosmogenic Isotopes: Archives and Causes" that was to be held 10–17 June 1992 in Riga, Latvia has been cancelled. Professors V. S. Veksler and G. E. Kocharov will try to reschedule the workshop in the future.

Publications

"Radiocarbon After Four Decades: An Interdisciplinary Perspective" has been published by Springer-Verlag New York and *RADIOCARBON*. This hardcover edition, the symposium volume for the commemorative meeting in Lake Arrowhead, California, 4–8 June 1990, is over 600 pages long. The book costs $89.00, with a 25% discount to subscribers, or $66.25. Please see our advertisement for ordering instructions.

1992 will be a very busy year for *RADIOCARBON*. Besides the Proceedings of the 14th International Radiocarbon Conference, we will also publish two other Special Issues, a new Calibration Issue (Special Editor: Minze Stuiver) and a Paleoastrophysics Issue (Special Editor: Paul E. Damon). The latter evolved from the Paleoastrophysics Workshop held at the Tucson conference.

In 1993, we are planning a Special Issue on Radiocarbon in Soils as an Indicator of Global Climate Change (Special Editor: Wallace S. Broecker). Our apologies to J.-M. Punning, Special Editor of an issue of radiocarbon literature from Eastern Europe and the Confederation of Independent States. We *will* publish this in 1993!

[RADIOCARBON, VOL. 34, NO. 1, 1992, P. 188]

LETTER TO THE EDITORS

27 February 1992

Dr. Austin Long
Ms. Renee Kra
RADIOCARBON
4717 E. Fort Lowell Road
Tucson, Arizona 85712

Dear Austin and Renee,

I read Punning's letter about the Association of Eastern European, Baltic and other laboratories with interest. It is important to realize that these laboratories face a somewhat different situation than many others. The fact that these labs have already decided to form their own organization does suggest some action be taken on the question of an International ^{14}C Organization.

From my point of view, I agreed to the Committee that was given the task of investigating the possibility of an "International Association of ^{14}C Laboratories," although I am not yet completely convinced of the merits of such an organization. It is useful for funding of *RADIOCARBON* subscriptions and back issues for laboratories that do not have access to hard currency. Perhaps a new function may be to assist those laboratories in difficulty with advice and so on.

We already have a limited program to help third-world laboratories by providing free ^{14}C dates. The question of the survival of the laboratories in Eastern Europe, the Baltics and the former Soviet republics is important, but requires a different solution. Clearly, they need some kind of encouragement. I think that their main goal at this time is to be able to generate funding from external sources. This could be done if they were to compete for ^{14}C contracts and business, which western ^{14}C labs routinely do. I think one of the problems is perhaps that these laboratories do not know how to approach this problem. Legal and structural problems may be involved also, *e.g.*, exchange controls and lack of convertibility of currency.

The expense of organizing a meeting of the Committee solely for the purpose of discussing this question seems to rule this out. Also, as you feel that *RADIOCARBON* should not be directly involved in arranging a meeting of this Committee, perhaps a solution would be to ask one of its members to collect opinions from all the others on how the new organization could be set up, how it would operate and how it would aid the labs mentioned above.

It is quite easy to contact most people by fax or telephone, with some persistence. I would suggest that perhaps Robert Hedges or Zhou Weijian would be ideal for this task.

Yours sincerely,

A. J. T. Jull
NSF-Arizona Accelerator Facility
for Radioisotope Analysis
The University of Arizona
Tucson, Arizona 85721 USA

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NOTICE TO READERS AND CONTRIBUTORS

Since its inception, the basic purpose of *RADIOCARBON* has been the publication of compilations of ^{14}C dates produced by various laboratories. These lists are extremely useful for the dissemination of basic ^{14}C information.

In recent years, *RADIOCARBON* has also been publishing technical and interpretative articles on all aspects of ^{14}C. We would like to encourage this type of publication on a regular basis. In addition, we will be publishing compilations of published *and unpublished* dates along with interpretative text for these dates on a regional basis. Authors who would like to compose such an article for his/her area of interest should contact the Managing Editor for information.

Other sections recently added to our regular issues include NOTES AND COMMENTS, LETTERS TO THE EDITOR, RADIOCARBON UPDATES and ANNOUNCEMENTS. Authors are invited to extend discussions or raise pertinent questions to the results of scientific investigations that have appeared on our pages. These sections include short, technical notes to relay information concerning innovative sample preparation procedures. Laboratories may also seek assistance in technical aspects of radiocarbon dating. Book reviews are also encouraged as are advertisements.

Manuscripts. Papers may now be submitted on both floppy diskettes and hard copy. When submitting a manuscript, include three hard copies, double-spaced. When the final copy is prepared after review, please provide a floppy diskette along with one hard copy. We will accept, in order of preference, WordPerfect 5.1 or 5.0, Microsoft Word, Wordstar or any IBM word-processing software program. ASCII files, MS DOS and CPM formatted diskettes are also acceptable. The diskettes should be either 3½" (720 k or 1.44 megabytes) or 5¼" (360 k or 1.2 megabytes). Radiocarbon papers should follow the recommendations in INSTRUCTIONS TO AUTHORS (this issue). Offprints are available upon request. Because Volume 34 is full, our deadline schedule for submitting manuscripts is:

For	*Date*
Vol. 35, No. 1, 1993	September 1, 1992
Vol. 35, No. 2, 1993	January 1, 1993
Vol. 35, No. 3, 1993	May 1, 1993

Half-life of ^{14}C. In accordance with the decision of the Fifth Radiocarbon Dating Conference, Cambridge, England, 1962, all dates published in this volume (as in previous volumes) are based on the Libby value, 5568 yr, for the half-life. This decision was reaffirmed at the 11th International Radiocarbon Conference in Seattle, Washington, 1982. Because of various uncertainties, when ^{14}C measurements are expressed as dates in years BP, the accuracy of the dates is limited, and refinements that take some but not all uncertainties into account may be misleading. The mean of three recent determinations of the half-life, 5730 ± 40 yr, (*Nature*, 1962, v. 195, no. 4845, p. 984), is regarded as the best value presently available. Published dates in years BP can be converted to this basis by multiplying them by 1.03.

AD/BC Dates. In accordance with the decision of the Ninth International Radiocarbon Conference, Los Angeles and San Diego, California, 1976, the designation of AD/BC, obtained by subtracting AD 1950 from conventional BP determinations is discontinued in *RADIOCARBON*. Authors or submitters may include calendar estimates as a comment, and report these estimates as cal AD/BC, citing the specific calibration curve used to obtain the estimate. Calibrated dates will now be reported as "cal BP" or "cal AD/BC" according to the consensus of the Twelfth International Radiocarbon Conference, Trondheim, Norway, 1985.

Measuring of $\delta^{14}C$. In Volume 3, 1961, we endorsed the notation Δ (Lamont VIII, 1961) for geochemical measurements of ^{14}C activity, corrected for isotopic fractionation in samples and in the NBS oxalic-acid standard. The value of $\delta^{14}C$ that entered the calculation of Δ was defined by reference to Lamont VI, 1959, and was corrected for age. This fact has been lost sight of, by editors as well as by authors, and recent papers have used $\delta^{14}C$ as the observed deviation from the standard. At the New Zealand Radiocarbon Dating Conference it was recommended to use $\delta^{14}C$ only for age-corrected samples. Without an age correction, the value should then be reported as percent of modern relative to 0.95 NBS oxalic acid (Proceedings of the 8th Conference on Radiocarbon Dating, Wellington, New Zealand, 1972). The Ninth International Radiocarbon Conference, Los Angeles and San Diego, California, 1976, recommended that the reference standard, 0.95 NBS oxalic acid activity, be normalized to $\delta^{13}C = -19‰$.

In several fields, however, age corrections are not possible. $\delta^{14}C$ and Δ, uncorrected for age, have been used extensively in oceanography, and are an integral part of models and theories. For the present, therefore, we continue the editorial policy of using Δ notations for samples not corrected for age.

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